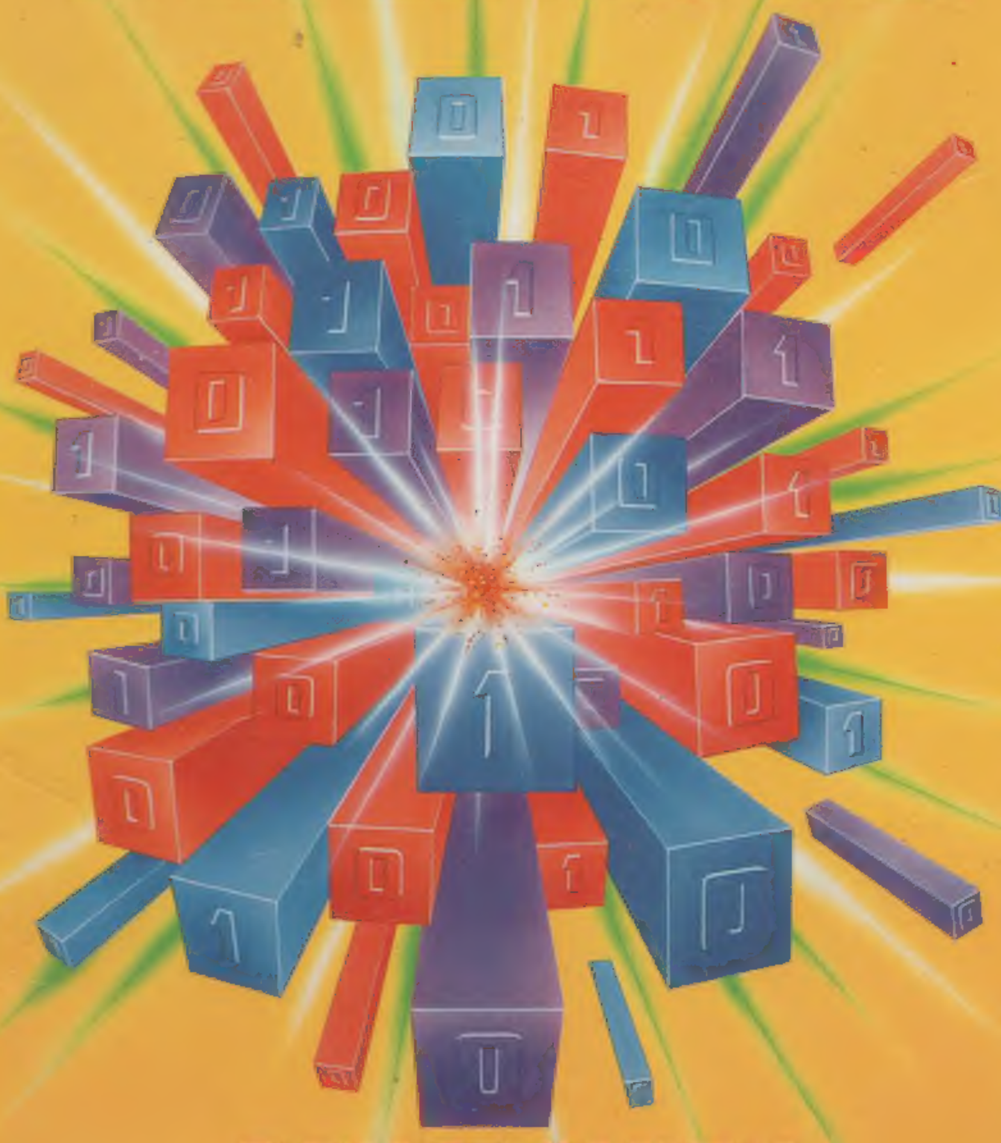
THE BBC MICRO MACHINE CODE PORTFOLIO

75 EXPERT ROUTINES



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The BBC Micro Machine Code Portfolio

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Contents

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Finally, to Richard Miles of Granada, a thank you for seeding the idea for the Portfolio in the first place.

Bruce Smith

Disks and cassettes of the programs in this book are available. Apply for details to:

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Chapter One
Introduction

The BBC Micro Machine Code Portfolio is aimed at providing the serious machine code programmer with an interesting and useful set of assembly language routines. In all, a selection of 75 programs from my own disk-based library are included, ranging from general purpose utility aids to BASIC and machine code programming to specific utilities that could form the basis of an interesting machine code compiler. Each of the assembler routines is provided as a uniquely line numbered procedure that can be *EXECuted back into a program any time it is required. Although the programs are written making full use of BASIC II's EQU functions, a solution is provided towards the end of this chapter that will enable BASIC I users to implement these functions with the absolute minimum of fuss.

The Portfolio is not aimed at the beginner. Many of the routines assume a rudimentary knowledge of the manipulative techniques involved. For this reason, the descriptive commentary of, say, a multibyte addition program may be kept to the looping and data manipulation means used rather than the principles of the actual addition itself. This does not mean to say that the Portfolio is presented with experts in mind – far from it. My own knowledge of machine code programming was facilitated by continuous trial and error programming, and at that time no books of this sort were available to help me along the way. Enter the program and use it as described in the text; in using the program and experimenting with it the real knowledge will be gained.

The contents of each chapter have been grouped together for ease of use. Chapters 2 to 9 provide the programming utilities which can make the programmer's life a merry one. These include function key definition printers, program variable dumps, a global search and replace utility and a program compacter.

Chapter 10 provides the mathematically biased routines. Four multibyte routines handle addition, subtraction, multiplication and

division. The remaining seven routines provide square root solutions and dual byte shifts.

Graphics are dealt with in Chapter 11, with just about every BASIC-type graphics command covered. This includes a useful routine using the interpreter-based *640 multiplication table to convert an X,Y screen coordinate into an absolute screen address. The graphics routines are particularly easy to group into a BASIC-driven menu to provide a simple graphics compiler (SGC).

All programs require data manipulation at some time and Chapter 12 supplies eleven procedures to sort, add, and delete items from a variety of lists and arrays. Screen interaction is important in making programs user-friendly, and Chapter 13 provides the routines to enable this to be performed with ease. Finally, Chapter 14 has grouped a few miscellaneous procedures together providing timing delays, counters and interrupt polling.

The Appendix contains a number of the Portfolio programs in a new form as bar code listings. Using the MEP bar code reader these may be read in directly from the pages of the book itself!

The correct procedure

As mentioned, each of the assembler routines are implemented as PROCedures, with each having its own range of line numbers. The procedure contains all the necessary coding to make the routine a stand-alone one. Because a procedure must be called from a program, each program contains several lines of BASIC to call first the PROC to assemble the machine code it contains and then demonstrate the type of application possible. This serves two functions; first, it assures you that you have entered the program correctly and also shows you how it works! If you flick through a few of the programs you'll notice that the lines of the PROC are given high line numbers in steps of 1 while the assemble and test routines use low line numbers. This is quite deliberate as it keeps the two parts of the program clearly separated.

To build up a library of these programs to disk or tape, the PROCedure can be save to tape. As the low line numbers are only, in effect, test routines these can be deleted so that only the procedure remains; and it is this that should be saved. I prefer to save my PROCedures as ASCII files rather than programs as this allows them to be added easily to other programs. The *SPOOL command is used to perform this. Choosing a suitable filename, the syntax is simply:

*SPOOL NAME

If you are using the cassette filing system then you'll need to start the cassette running. If you are using disks then these will already be whirling around. So, now simply LIST the program. As the listing appears onto the screen it will also be written to the current filing system. When the program has finished listing enter

*SPOOL

once again to complete the transfer from memory to filing medium. You will probably have noticed that the filename used in the *SPOOL command was not enclosed within the quotes normally associated with a SAVE. This is acceptable as the MOS does not expect them - though using them will have no adverse effect.

Once all programs have been treated in this way they are ready to be used in a greater scheme of things! One point - when building up a large library of procedures it is very important to catalogue them, in a book, on another disk or tape, or on the front of each tape or disk. This catalogue should depict the program's name, line numbers and function as this will be invaluable when it comes to using them at a later date.

Once a program has been saved as a spooled file it can be loaded back into memory using the MOS-based *EXEC command. To load the previously spooled file you use

*EXEC NAME

Again, the quotes around the filename are not obligatory. When the operating system encounters the file it treats each line of it as though it had been typed in at the keyboard and as the return character at the end of the line is reached the line is entered into memory. This is the main reason for using unique line numbers within procedures, as it enables several procedures to be *EXECuted into memory without fear of overwriting any program lines already there.

A demonstration

To show the flexibility of the programs within the Portfolio and their use, study the following demonstration. Suppose a short graphics routine is required that will select a MODE 4 screen and draw ■ dotted line from the coordinate 200.200 to 900,600. First, the three desired files to perform a MODE, MOVE and PLOT must be loaded

in (these can be found in Chapter 13). Depending on the filenames you have chosen, this might take the form of executing the following commands one by one:

```
*EXEC mode
*EXEC move
*EXEC plot
```

The resultant listing forms part of Program 1.1. Next, a BASIC primer needs to be written to call each PROC and pass the relevant information through the arguments of the procedural call. First, PROCmode:

```
20 PROCmode (4, &A00)
```

The PROCedure is called passing the mode number, 4 into the variable 'action' and the assembly address, &A00, into 'addr'. Next, the graphics cursor must be moved. The problem here is that we do not really want to have to calculate the new value to be assigned to 'addr' for the code assembly; instead we can simply use the program counter itself in the form of P%. Thus line 30 becomes

```
30 PROCmove (200, 200, P%)
```

The move coordinates are 200,200 and the PROCmove code is assembled from P%. Finally PROCplot can be treated in the same way to give

```
40 PROCplot (21,900,600,P%)
```

where 21 is the plot code for an absolute dotted line, 900,600 the final coordinates and P% the assembly address.

Now each PROCedure will assemble its code as a subroutine call. To implement the machine code, a short procedure must be written that will call each subroutine in turn, thus:

```
JSR mode  \  set up MODE
JSR move  \  move graphics cursor
JMP plot  \  draw line and return
```

Program 1.1 lists the final program and, by way of proof of the output, Figure 1.1 lists the assembler listing produced when RUN.

When using this modular-cum-structured assembly approach, the use of the OPT command must be borne in mind. If the OPT command is omitted then the default value of 3 will be assumed by the assembler. In the case of the above example this was not too much of a problem, but there are occasions when it will be! For example, if

```
  10 REM *** USING THE PORTFOLIO ***
  20 PROCmode (4,&A00)
  30 PROCmove (200,200,P%)
  40 PROCplot (21,900,600,P%)
  50 PROCassemble(P%)
  60 CALL test
  70 END
  80 :
 100 DEF PROCassemble (addr)
 110 P%=addr
 120 [
 130 .test
 140             JSR mode
 150             JSR move
 160             JMP plot
 170 ]
 180 ENDPROC
 200 :
6000 DEF PROCmode (action,addr)
6001 P%=addr
6002 [
6003 .mode
6004             LDA #22
6005             JSR &FFEE
6006             LDA #action
6007             JSR &FFEE
6008             RTS
6009 ]
6010 ENDPROC
6180 DEF PROCmove(xpos,ypos,addr)
6181 P%=addr
6182 [
6183 .move
6184            LDA #25
6185            JSR &FFEE
6186            LDA #4
6187            JSR &FFEE
6188            LDA #xpos MOD 256
6189            JSR &FFEE
6190            LDA #xpos DIV 256
6191            JSR &FFEE
6192            LDA #ypos MOD 256
6193            JSR &FFEE
6194            LDA #ypos DIV 256
6195            JSR &FFEE
6196            RTS
6197 ]
6198 ENDPROC
```

Program 1.1. Spooling procedures to form a graphics program.

```
6220 DEF PROCplot(code,xcord,ycord,addr)
6221 P%=addr
6222 [
6223 .plot
6224            LDA #25
6225            JSR &FFEE
6226            LDA #code
6227            JSR &FFEE
6228            LDA #xcord MOD 256
6229            JSR &FFEE
6230            LDA #xcord DIV 256
6231            JSR &FFEE
6232            LDA #ycord MOD 256
6233            JSR &FFEE
6234            LDA #ycord DIV 256
6235            JSR &FFEE
6236            RTS
6237 ]
6238 ENDPROC
```

Program 1.1. Spooling procedures to form a graphics program *(cont.)*.

```
>RUN
0A00
0A00           .mode
0A00 A9 16     LDA #22
0A02 20 EE FF JSR &FFEE
0A05 A9 04     LDA #action
0A07 20 EE FF JSR &FFEE
0A0A 60        RTS
0A0B
0A0B           .move
0A0B A9 19     LDA #25
0A0D 20 EE FF JSR &FFEE
0A10 A9 04     LDA #4
0A12 20 EE FF JSR &FFEE
0A15 A9 C8     LDA #xpos MOD 256
0A17 20 EE FF JSR &FFEE
0A1A A9 00     LDA #xpos DIV 256
0A1C 20 EE FF JSR &FFEE
0A1F A9 C8     LDA #ypos MOD 256
0A21 20 EE FF JSR &FFEE
0A24 A9 00     LDA #ypos DIV 256
0A26 20 EE FF JSR &FFEE
0A29 60        RTS
0A2A
0A2A           .plot
0A2A A9 19     LDA #25
0A2C 20 EE FF JSR &FFEE
0A2F A9 15     LDA #code
```

Fig. 1.1. Assembler listing produced by Program 1.1.

```
0A31 20 EE FF JSR &FFEE
0A34 A9 84    LDA #xcord MOD 256
0A36 20 EE FF JSR &FFEE
0A39 A9 03    LDA #xcord DIV 256
0A3B 20 EE FF JSR &FFEE
0A3E A9 58    LDA #ycord MOD 256
0A40 20 EE FF JSR &FFEE
0A43 A9 02    LDA #ycord DIV 256
0A45 20 EE FF JSR &FFEE
0A48 60       RTS
0A49
0A49          .test
0A49 20 00 0A JSR mode
0A4C 20 0B 0A JSR move
0A4F 4C 2A 0A JMP plot
```

Fig. 1.1. Assembler listing produced by Program 1.1 *(cont.)*.

assembly is performed on a conditional basis then it may be desirable to suppress it altogether using OPT 2 lest it corrupt some vital screen detail. Alternatively, a FOR...NEXT combination may be imperative to suppress errors during a first pass to assign forward branch labels. There is no simple way around this. A universal solution would be to include a

FOR pass=0 TO 2 STEP 2

line in all procedures. I prefer to add the OPT commands as required, but the choice is yours.

The BASIC solution

BASIC II provides several enhancements over its predecessor BASIC I. The most useful of these are the EQU functions which are implemented as pseudo-opcodes. These functions and their operations are:

EQUB : assemble specified byte
EQUW : assemble specified word (2 bytes)
EQUD : assemble specified double word (4 bytes)
EQUS : assemble specified string as ASCII characters

Numerous programs in the Portfolio take advantage of these commands, which would therefore make them inoperable on Beebs with BASIC I. These commands can be simulated quite simply using the ability of the FN command.

Program 1.2 lists the function definitions plus a suitable demonstration. Taking each definition as it appears in the program, FNequs (lines 500 to 530) uses the program counter variable P% as the string argument for the ASCII character string passed into the function via 'strings'. Before exit, P% is incremented by the length of the string.

FNequb (lines 550 to 580) takes the value 'byte%' and simply pokes it into memory at P%. The program counter is incremented by one and completes. FNequw (lines 600 to 640) is an extension and provides two pokes at the position of P%. The high and low bytes are

```
 10 REM ** SIMULATING BASIC II EQU **
 20 P%=&900
 30 [
 40             LDA #255
 50             OPT FNequs("TEST",3)
 60             LDX #0
 70             OPT FNequb(6,3)
 80             LDY #&33
 90             OPT FNequw(&FFFF,3)
100             STX &70
110             OPT FNequd(&12345678,3)
120             LDX #&AA
130             RTS
140 ]
150 END
160 :
500 DEF FNequs(string$,opt)
510 $P%=string$
520 P%=P%+LEN(string$)
530 =opt
540 :
550 DEF FNequb(byte%,opt)
560 ?P%=byte%
570 P%=P%+1
580 =opt
590 :
600 DEF FNequw(word%,opt)
610 ?P%=word% MOD 256
620 P%?1=word% DIV 256
630 P%=P%+2
640 =opt
650 :
660 DEF FNequd(double%,opt)
670 !P%=double%
680 P%=P%+4
690 =opt
```

Program 1.2. Simulating the BASIC II EQU functions in BASIC I.

extracted from 'word' using the MOD and DIV operators. Finally, FNequd (lines 660 to 690) uses the word indirection operator to pling its four bytes into memory.

The assembler text (lines 40 to 130) shows how each procedure should be called. The second parameter in each of the OPT FN calls (3 throughout) simply refers to the OPT selection and this should be seeded as required by the program. To end with, Figure 1.2 shows the assembler listing provided when running this program, while the hex dump in Figure 1.3 shows that each FN has indeed performed the required task.

```
>RUN
0900
0900 A9 FF     LDA #255
0906           OPT FNequs("TEST",3)
0906 A2 00     LDX #0
0909           OPT FNequb(6,3)
0909 A0 33     LDY #&33
090D           OPT FNequw(&FFFF,3)
090D 86 70     STX &70
0913           OPT FNequd(&12345678,3)
0913 A2 AA     LDX #&AA
0915 60        RTS
```

Fig. 1.2. Assembler listing produced by Program 1.2.

```
900  A9
901  FF
902  54
903  45
904  53
905  54
906  A2
907  0
908  6
909  A0
90A  33
90B  FF
90C  FF
90D  86
90E  70
90F  78
910  56
911  34
912  12
913  A2
914  AA
915  60
```

Fig. 1.3. A hex dump of the code assembled by Program 1.2, showing that the functions have worked.

Chapter Two

Function Key Reader

Virtually all the toolbox type of commercial ROM packages around these days include a facility for printing any resident function key definitions. Many, though, are incomplete and only deal with keys 0 through to 10, neglecting keys 11 to 15. Writing a custom-built routine to handle printing definitions present in all sixteen function keys is a relatively easy task providing a working knowledge of the function key buffer is to hand. Two programs are presented here; the first is reprinted from the April 1984 edition of *Acorn User* while the second is an improved version. The two differ in that the former,

Key	Pointer byte
0	&B00
1	&B01
2	&B02
3	&B03
4	&B04
5	&B05
6	&B06
7	&B07
8	&B08
9	&B09
10	&B0A
11	&B0B
12	&B0C
13	&B0D
14	&B0E
15	&B0F
TOP	&B10

Fig. 2.1. Function key associated bytes.

Program 2.1, is not capable of printing multistatement single key definitions whereas the latter, Program 2.2, is. The advantage in using the former is the saving in memory overheads as it requires only half the memory space required by the latter.

The function key buffer is located in page &B of block zero RAM occupying the bytes &B00 to &BFF inclusive. With the exception of the first seventeen bytes, all of this is used to hold the key definitions in ASCII format; commands are not tokenised. These first seventeen bytes, &B00 to &B10, are the key pointer bytes and Figure 2.1 details the bytes associated with the individual keys. Monitoring each of these bytes as key definitions are entered, modified and deleted gives an insight into their purpose. Figure 2.2 is a hex dump of the start of the buffer after a hard break, either when you have switched on or the CTRL-BREAK sequence is carried out. At this stage the buffer contains nothing but &10 in every byte.

```
0B00 : 10 10 10 10 10 10 10 10 ........
0B08 : 10 10 10 10 10 10 10 10 ........
0B10 : 10 10 10 10 10 10 10 10 ........
0B18 : 10 10 10 10 10 10 10 10 ........
0B20 : 10 10 10 10 10 10 10 10 ........
0B28 : 10 10 10 10 10 10 10 10 ........
0B30 : 10 10 10 10 10 10 10 10 ........
0B38 : 10 10 10 10 10 10 10 10 ........
```

Fig. 2.2. Key buffer after switch-on.

Figure 2.3 depicts the same area of the key buffer after a short definition has been entered into f0 thus:

*KEY 0 CLS ¦M

The dump shows that the ASCII string CLS is present but that the return sequence '¦M' has been replaced with the more conventional ASCII return character &0D. It is also obvious from the dump that the key pointer bytes have altered. The first byte at &B00 is, we know from Figure 2.1, associated with *KEY0, and this byte still contains

```
0B00 : 10 14 14 14 14 14 14 14 ........
0B08 : 14 14 14 14 14 14 14 14 ........
0B10 : 14 43 4C 53 0D 10 10 10 .CLS....
0B18 : 10 10 10 10 10 10 10 10 ........
0B20 : 10 10 10 10 10 10 10 10 ........
0B28 : 10 10 10 10 10 10 10 10 ........
0B30 : 10 10 10 10 10 10 10 10 ........
0B38 : 10 10 10 10 10 10 10 10 ........
```

Fig. 2.3. Key buffer after executing *KEY0 CLS ¦M.

&10 or 16 decimal. Counting sixteen bytes from this location we arrive at the first character in the *KEY 0 definition. The remaining key pointer bytes now all contain &14 or 20 decimal; counting 20 bytes from the *KEY 0 pointer brings us to the last byte of the *KEY 0 definition, the carriage return character at &B14.

Figure 2.4 shows the buffer after a further key has been defined, thus:

*KEY 9 AUTO ¦M

The ASCII characters of the new definition are entered into the buffer immediately after the last definition. The key pointer byte for *KEY 9 at &B09 still contains &14 while the *KEY0 byte remains at &10. All the other key pointer bytes have been updated to hold &19 or 25 decimal. Starting from &B00 and counting 25 bytes brings us to &B19, the last byte defined in the buffer.

```
0B00 : 10 19 19 19 19 19 19 19 ........
0B08 : 19 14 19 19 19 19 19 19 ........
0B10 : 19 43 4C 53 0D 41 55 54 .CLS.AUT
0B18 : 4F 0D 10 10 10 10 10 10 O.......
0B20 : 10 10 10 10 10 10 10 10 ........
0B28 : 10 10 10 10 10 10 10 10 ........
0B30 : 10 10 10 10 10 10 10 10 ........
0B38 : 10 10 10 10 10 10 10 10 ........
```

Fig. 2.4. Key buffer after executing *KEY9 AUTO ¦M.

It is worth looking at what happens in the buffer if a function key is redefined. Figure 2.5 shows the effect of placing a longer defintion into *KEY 0 than was already present, thus:

*KEY 0 VDU 7 ¦M

What has happened now is that the previous *KEY0 definition has been deleted, the remaining definition(s) shuffled up to the front of the buffer and the new *KEY0 definition added onto the end. Each of the key pointer bytes have been adjusted to point to the correct

```
0B00 : 15 1B 1B 1B 1B 1B 1B 1B ........
0B08 : 1B 10 1B 1B 1B 1B 1B 1B ........
0B10 : 1B 41 55 54 4F 0D 56 44 .AUTO.VD
0B18 : 55 20 37 0D 10 10 10 10 U 7.....
0B20 : 10 10 10 10 10 10 10 10 ........
0B28 : 10 10 10 10 10 10 10 10 ........
0B30 : 10 10 10 10 10 10 10 10 ........
0B38 : 10 10 10 10 10 10 10 10 ........
```

Fig. 2.5. Key buffer after redefining f0 as *KEY0 VDU 7 ¦M.

location. *KEY 9 was defined as AUTO and the pointer byte at &B09 now holds &10 giving the offset from &B00 to the start of the definition. *KEY 0 which is now tacked onto the end of the *KEY 9 definition has had its pointer offset reset to &15 or 21 decimal. The remaining pointer bytes have also been adjusted to all give the correct offset to the last used byte in the buffer. &1B or 27 decimal, which when added to &B00 gives &B1B.

The key pointer area contains an extra 'general' byte at &B10 that we have not yet mentioned. This byte is, in fact, the TOP pointer in the buffer and always holds the byte offset into the buffer of the last used location. The MOS uses this byte to test if a *KEY definition is present when a function key has been defined. If the key pointer byte and the TOP pointer byte are the same, the MOS inserts the definition directly after the last definition (as pointed to by the pointer and TOP bytes). If, on the other hand, the pointer byte and TOP byte are different, the MOS knows that a definition is already present for the function key just defined and that it must do some reshuffling of the bytes in the buffer.

Program 2.1

Program 2.1 is the first of the function key definition printer programs. Called PROCkeys1, it occupies 63 lines between 1000 and 1063. All processor registers are used and the object code occupies 126 bytes anywhere in memory as specified by the variable 'addr'.

```
  10 REM *** FUNCTION KEY PRINTER ***
  20 REM *(C) Bruce Smith & Acorn User*
  30 oswrch=&FFEE
  40 osasci=&FFE3
  50 PROCkeys1 (&C00)
  60 *KEY0 CALL &C00:M
  70 END
  80 :
1000 DEF PROCkeys1(addr)
1001 LOCAL key, pointer
1002 key=&B00
1003 pointer=&B10
1004 FOR pass=0 TO 3 STEP3
1005 P%=addr
1006 [OPT pass
1007                LDX #0
1008 .main_loop
```

Program 2.1. PROCkeys1 – a simple function key lister.

```
1009                  TXA
1010                  ASL A
1011                  TAX
1012                  JSR print_word_key
1013                  LDA number_table,X
1014                  JSR oswrch
1015                  LDA number_table+1,X

1016                  JSR oswrch
1017                  TXA
1018                  LSR A
1019                  TAX
1020                  LDA #&20
1021                  JSR oswrch
1022                  LDA key,X
1023                  CMP pointer
1024                  BNE over
1025                  JMP update
1026 .over
1027                  TAY
1028                  INY
1029 .next_character
1030                  LDA key,Y
1031                  CMP #13
1032                  BEQ carriage_return
1033                  JSR oswrch
1034                  INY
1035                  BNE next_character
1036 .carraige_return
1037                  LDA #ASC"|"
1038                  JSR oswrch
1039                  LDA #ASC"M"
1040                  JSR oswrch
1041 .update
1042                  LDA#13
1043                  JSR osasci
1044                  INX
1045                  CPX#16
1046                  BNEmain_loop
1047                  RTS
1048 .print_word_key
1049                  LDY#6
1050 .next_letter
1051                  LDA spell_key,Y
1052                  JSR oswrch
1053                  DEY
1054                  BNE next_letter
1055                  RTS
```

Program 2.1. PROCkeys 1 - a simple function key lister *(cont.)*

```
1056 .number_table
1057                    EQUS" 0 1 2 3 4 5 6 7 "
1058                    EQUS"8 9101112131415 "
1059 .spell_key
1060                    EQUS "  YEK* "
1061 ]
1062 NEXT
1063 ENDPROC
```

Program 2.1. PROCkeys 1 – a simple function key lister *(cont.)*.

Converting the hard facts of Function Key Buffer operation into some suitable machine code is relatively easy and the main areas of coding are straightforward. From this we can see the main routines of the code which, in everyday terms, are a follows:

(a) Print the string '*KEY' followed by the current key number (therefore we need a key counter!).
(b) Obtain the key pointer and if the same as the TOP pointer move onto the next function key.
(c) Else increment key pointer and print the definition string until the RETURN character is found.
(d) Print |M and do a RETURN.
(e) Increment the function key counter.
(f) Repeat the whole process until all sixteen keys have been printed.

The X register is used to keep a count of the current key being investigated so initially this is set to zero (line 1007). The register is also used as an index into the key number look-up table (lines 1056 to 1058) where each of the ASCII codes for the key number occupies two bytes. To ensure that the correct offset is located, the key count must be multiplied by two using an arithmetic shift left (lines 1009 to 1011). The word '*KEY' and the current key number are printed using the subroutine calls of lines 1012 to 1016.

A definition present test is performed in line 1022 and 1023 and a branch over executed (line 1024) if one is found. A simple index, extract and print routine is used to print the definition string (lines 1036 to 1040) before the key count in the index register is updated (lines 1041 to 1047).

Program 2.2

Program 2.2 is, in essence, the same as Program 2.1 but extra coding

has been incorporated into the listing to test for multiple definitions and control codes. The procedure is called PROCkeys2 and assumes line numbers 1070 to 1189 inclusive. The source code generates 246 bytes of hex assembled at 'addr'.

```
  10 REM *FUNCTION KEY DEFINITIONS V2*
  20 PROCkeys2 (&A00)
  30 *KEY0 CALL &A00:M
  40 END
  50 :
1070 DEF PROCkeys2 (addr)
1071 FOR pass=0 TO 3 STEP3
1072 P%=addr
1073 [
1074           OPT pass
1075 .entry
1076           LDA #0
1077           STA key
1078           STA offset
1079 .mainloop
1080           JSR &FFE7
1081           JSR printwordkey
1082           LDX key
1083           LDA numbertable,X
1084           INX
1085           JSR &FFEE
1086           LDA numbertable,X
1087           JSR &FFEE
1088           INX
1089           STX key
1090           LDA #32
1091           JSR &FFEE
1092           LDX offset
1093           LDA &B00,X
1094           STA keystart
1095           INC keystart
1096           LDA &B10
1097           STA endpointer
1098           LDX #&F
1099 .keyend
1100           LDA &B00,X
1101           CMP endpointer
1102           BCS nexttry
1103           CMP keystart
1104           BCC nexttry
1105           STA endpointer
1106 .nexttry
1107           DEX
```

Program 2.2. PROCkeys2 – the complete function key lister.

```
1108            BPL keyend
1109            LDA endpointer
1110            CMP keystart
1111            BCC nextkey
1112            LDX keystart
1113 .printdef
1114            LDA &B00,X
1115            CMP #128
1116            BCC asciichr
1117            PHA
1118            LDA #ASC"|"
1119            JSR &FFEE
1120            LDA #ASC"!"
1121            JSR &FFEE
1122            PLA
1123            AND #&7F
1124 .asciichr
1125            CMP #32
1126            BCS notcontrol
1127            PHA
1128            LDA #ASC"|"
1129            JSR &FFEE
1130            PLA
1131            CLC
1132            ADC #64
1133            JSR &FFEE
1134            JMP nextcharacter
1135 .notcontrol
1136            CMP #127
1137            BNE over
1138            LDA #ASC"|"
1139            JSR &FFEE
1140            LDA #ASC"?"
1141            JSR &FFEE
1142            JMP nextcharacter
1143 .over
1144            CMP#124
1145            BNE not
1146            LDA #ASC"|"
1147            JSR &FFEE
1148            JSR &FFEE
1149            JMP nextcharacter
1150 .not
1151            JSR &FFEE
1152 .nextcharacter
1153            CPX endpointer
1154            BEQ nextkey
1155            INX
```

Program 2.2. PROCkeys2 – the complete function key lister *(cont.)*.

```
1156              JMP printdef
1157 .nextkey
1158              INC offset
1159              LDA offset
1160              CMP #16
1161              BNE notfinished
1162              JSR &FFE7
1163              RTS
1164 .notfinished
1165              JMP mainloop
1166 .printwordkey
1167              LDY #6
1168 .nextletter
1169              LDA spellkey,Y
1170              JSR &FFEE
1171              DEY
1172              BNE nextletter
1173              RTS
1174 .numbertable
1175              EQUS" 0 1 2 3 4 5 6 7 "
1176              EQUS"8 9101112131415"
1177 .spellkey
1178              EQUS"  YEK* "
1179 .key
1180              EQUB 0
1181 .keystart
1182              EQUB 0
1183 .endpointer
1184              EQUB 0
1185 .offset
1186              EQUB 0
1187 ]
1188 NEXT
1189 ENDPROC
```

Program 2.2. PROCkeys2 - the complete function key lister *(cont.)*.

The definition printing routine (line 1113) begins by testing the definition for a character code greater than 128 (entered previously with the '|!' sequence). If one is present this sequence is printed; either way, control progresses to line 1124 where a control character (less than &32) is tested for. If a control character is found, the '|' character is printed followed by the ASCII code of the control character representation, obtained by adding &40 to it. Thus CNTR-L is printed as '|L'.

The end_pointer bytes are used to keep track of the length of the entered key definition as previously calculated by the key_end

coding (lines 1099 to 1112), and the print_def loop continues until the entire function key definition is printed. The main_loop is executed sixteen times to print all the function key definitions. The final output of this program is shown in Figure 2.6.

```
*KEY  0 CALL &A00|M
*KEY  1 CLS|M
*KEY  2 *GREPL|M
*KEY  3 LIST|M
*KEY  4 *ASSFORM|M
*KEY  5 *INSPECT
*KEY  6 *BASFORM|M
*KEY  7 FORN=&70 TO &7F:P.?N:N.|M
*KEY  8 *EXMON|M
*KEY  9 *BASIC|M
*KEY 10 OLD|MLIST|M
*KEY 11
*KEY 12
*KEY 13
*KEY 14
*KEY 15
```

Fig. 2.6. Typical output of Program 2.2.

Program fact sheets

Function key printers

Program 2.1

Proc title	: PROCkeys1
Line numbers	: 1000 to 1063
Variables required	: addr
Length	: 126 bytes
Zero page requirements	: none
Registers changed	: A, X, Y

Program 2.2

Procedure title	: PROCkeys2
Line numbers	: 1070 to 1189
Variables required	: addr
Length	: 246 bytes
Zero page requirements	: none
Registers changed	: A, X, Y

Chapter Three
Program Information

Two programming utilities are provided in this chapter. Program 3.1 lists the status of the various BASIC pseudo-variables in addition to displaying the length of the program currently under development and the number of bytes remaining available for use. To complement this, Program 3.2 when called will list every variable currently defined within a BASIC program (except the resident integer variables A% to Z%), and this includes assembler labels. This is particularly useful in long programs when it is difficult to keep a mental track of the variable names you have already chosen and thus avoids the infuriating situation that can occur when you use the same variable name twice and wonder why the program will just not work as it should!

Program status

PROCinfo is the assembler procedure to generate the source code for the info program. I have given the name 'info' to the procedure simply because it is more representative to the program's function. I would

```
  10 REM *** PROGRAM INFORMATION ***
  20 himem=HIMEM
  30 himem=himem-&200
  40 HIMEM=himem
  50 PROCinfo (&70,HIMEM)
  60 *KEY0 CALL HIMEM:M
  70 END
  80 :
1200 DEF PROCinfo (current,addr)
1201 FOR pass=0 TO 3 STEP3
1202 P%=addr
1203 [
```

Program 3.1. PROCinfo – provides details on system pseudo-variables.

```
1204            OPT pass
1205            LDX #title MOD 256
1206            LDY #title DIV 256
1207            JSR print_message
1208 .do_page
1209            LDX #message1 MOD 256
1210            LDY #message1 DIV 256
1211            JSR print_message
1212            LDA &18
1213            JSR hex_out
1214            LDA #0
1215            JSR hex_out
1216            JSR &FFE7
1217 .do_top
1218            LDX #message4 MOD 256
1219            LDY #message4 DIV 256
1220            JSR print_message
1221            LDA &13
1222            JSR hex_out
1223            LDA &12
1224            JSR hex_out
1225            JSR &FFE7
1226 .do_himem
1227            JSR &FFE7
1228            LDX #message2 MOD 256
1229            LDY #message2 DIV 256
1230            JSR print_message
1231            LDA &7
1232            JSR hex_out
1233            LDA &6
1234            JSR hex_out
1235            JSR &FFE7
1236 .do_lomem
1237            LDX #message3 MOD 256
1238            LDY #message3 DIV 256
1239            JSR print_message
1240            LDA &1
1241            JSR hex_out
1242            LDA &0
1243            JSR hex_out
1244            JSR &FFE7
1245            JSR &FFE7
1246 .do_size
1247            LDX #message5 MOD 256
1248            LDY #message5 DIV 256
1249            JSR print_message
1250            SEC
1251            LDA &13
```

Program 3.1. PROCinfo – provides details on system pseudo-variables *(cont.)*.

```
1252             SBC &18
1253             JSR hex_out
1254             LDA &12
1255             JSR hex_out
1256             LDX #bytes MOD 256
1257             LDY #bytes DIV 256
1258             JSR print_message
1259 .do_next_free
1260             LDX #message6 MOD 256
1261             LDY #message6 DIV 256
1262             JSR print_message
1263             LDA &3
1264             JSR hex_out
1265             LDA &2
1266             JSR hex_out
1267             JSR &FFE7
1268             JSR &FFE7
1269 .memory_left
1270             LDX #message7 MOD 256
1271             LDY #message7 DIV 256
1272             JSR print_message
1273             SEC
1274             LDA &6
1275             SBC &2
1276             STA store
1277             LDA &7
1278             SBC &3
1279             JSR hex_out
1280             LDA store
1281             JSR hex_out
1282             LDX #bytes MOD 256
1283             LDY #bytes DIV 256
1284             JSR print_message
1285             RTS
1286 .print_message
1287             STX current
1288             STY current+1
1289             LDY #0
1290 .loop
1291             LDA (current),Y
1292             BMI all_done
1293             JSR &FFE3
1294             INY
1295             BNE loop
1296 .all_done
1297             RTS
1298 .hex_out
1299             PHA
```

Program 3.1. PROCinfo – provides details on system pseudo-variables *(cont.)*.

```
1300            LSR A
1301            LSR A
1302            LSR A
1303            LSR A
1304            SED
1305            CLC
1306            ADC #&90
1307            ADC #&40
1308            CLD
1309            JSR &FFEE
1310            PLA
1311            AND #15
1312            SED
1313            CLC
1314            ADC #&90
1315            ADC #&40
1316            CLD
1317            JMP &FFEE
1318 .title EQUB 12
1319            EQUS"    Program"
1320            EQUS" Information Service"
1321            EQUD &0D0D0D0D
1322            EQUB 255
1323 .message1
1324            EQUS"PAGE  :  &"
1325            EQUB 255
1326 .message2
1327            EQUS"HIMEM :  &"
1328            EQUB 255
1329 .message3
1330            EQUS"LOMEM :  &"
1331            EQUB 255
1332 .message4
1333            EQUS"TOP   :  &"
1334            EQUB 255
1335 .message5
1336            EQUS"Program Size=&"
1337            EQUB 255
1338 .message6
1339            EQUS"Next Free Location=&"
1340            EQUB 255
1341 .message7
1342            EQUS"Memory Remaining=&"
1343            EQUB 255
1344 .bytes
1345            EQUS" bytes"
1346            EQUD &0D0D
1347            EQUB 255
```

Program 3.1. PROCinfo – provides details on system pseudo-variables *(cont.)*.

```
1348 .store
1349             EQUB 0
1350 ]
1351 NEXT
1352 ENDPROC
```

Program 3.1. PROCinfo – provides details on system pseudo-variables *(cont.)*.

suggest, however, that it is saved to tape or disk with the filename STATUS. This is because INFO is generally recognised as a disk filing system command and therefore the command *INFO could not be used to load and run the program from disk whereas *STATUS would be acceptable. When executed, the program prints the hexadecimal values of the following:

PAGE
HIMEM
LOMEM
TOP
Program size
Next free location
Memory remaining

All the information required to calculate each of these values can be found in zero page. Figure 3.1 lists the byte allocation for the first couple of dozen locations.

The assembler is quite straightforward and is split into easy-to-handle segments. The screen information title is first printed onto the screen using the print_message subroutine (lines 1286 to 1297). The address of the string to be printed is transferred to the subroutine via the index registers. On return, the relevant data is extracted from zero

&00 - &01	: LOMEM
&02 - &03	: VARTOP (top of variables)
&04 - &05	: Basic Stack Pointer
&06 - &07	: HIMEM
&08 - &09	: ERL
&0A	: Text pointer index
&0B - &0C	: Text pointer
&0D - &11	: RND seed
&12 - &13	: TOP
&16 - &17	: Error vector
&18	: PAGE byte

Fig. 3.1. Assignment of first 24 zero page bytes.

page and printed in hexadecimal format using a fairly standard hex to ASCII print routine, 'hex_out' (lines 1298 and 1317).

The values of PAGE, TOP, HIMEM,LOMEM and the next free location can be obtained directly from the BASIC workspace. The other values must be calculated, which generally involves a simple two-byte subtraction. Program size is calculated by subtracting TOP from PAGE and the amount of memory remaining by subtracting the top of variables (termed VARTOP by me!) from HIMEM. The actual value of VARTOP is not displayed by the program but could be simply added if so required.

The 'hex_out' routine works four bits at a time. Taking the high nibble first (as this is the first printed working left to right) and moving this into the low nibble, the conversion is performed using decimal addition with the decimal flag set with SED. The decimal addition of &90 converts the binary values 0 to 9 into the range &90 to &99 with the carry flag set. The addition of a further &40 converts these values to the range &30 to &39 with the carry set, which corresponds to the correct ASCII codes for the values 0 to 9. If the original nibble held &A to &F, adding &90 gives values in the range &0 to &5 (remember we are working with decimal addition). Addition of a further &40 with the carry set gives a final result in the range &41 to &46, the ASCII codes for A to F. The low nibble is treated in the same manner to produce the second digit before the decimal flag is cleared.

Using STATUS is straightforward: just perform a CALL to the assembly address. The BASIC primer generates the 372 bytes of code above a lowered HIMEM and can be called using function key 0. Figure 3.2 shows a typical output of the machine code.

```
      Program Information Service

PAGE  :  &1C00
TOP   :  &2559

HIMEM :  &7A00
LOMEM :  &2559

Program Size=&0959 bytes

Next Free Location=&26C7

Memory Remaining=&5339 bytes
```

Fig. 3.2. Typical output produced by Program 3.2.

Variable lister

PROCvars generates a useful variable lister that occupies a compact 103 bytes of memory, the cassette / RS 423 buffer in the demonstration. Five bytes of workspace are required in addition, and two bytes of these must be in zero page to facilitate indirect addressing.

```
   10 REM *** LIST ALL PROGRAM VARIABLES
 ***
   20 PROCvars(&70,&71,&73,&A00)
   30 *KEY 1 CALL&A00|M
   40 END
   50 :
 1400 DEF PROCvars(asc,varpointer,varstr
ing,addr)
 1401 FOR pass=0 TO 3 STEP 3
 1402 P%=addr
 1403 [           OPT pass
 1404 .variables
 1405           LDA #12
 1406           JSR &FFEE
 1407           LDA #14
 1408           JSR &FFEE
 1409           LDA #65
 1410           STA asc
 1411           LDA #&82
 1412           STA varpointer
 1413           LDA #4
 1414           STA varpointer+1
 1415 .loop
 1416           LDY #1
 1417           LDA (varpointer),Y
 1418           BEQ update
 1419           STA varstring+1
 1420           LDY #0
 1421           LDA (varpointer),Y
 1422           STA varstring
 1423 .next_var
 1424           LDA #13
 1425           JSR &FFE3
 1426           LDA asc
 1427           JSR &FFE3
 1428           LDY #2
 1429 .print_loop
 1430           LDA ( varstring),Y
 1431           BEQ end_print
```

Program 3.2. PROCvars - lists all program variables.

```
1432            JSR&FFE3
1433            INY
1434            JMP print_loop
1435 .end_print
1436            LDY #1
1437            LDA ( varstring),Y
1438            BEQ update
1439            TAX
1440            DEY
1441            LDA (varstring),Y
1442            STA varstring
1443            STX varstring+1
1444            JMP next_var
1445 .update
1446            LDA #2
1447            CLC
1448            ADC varpointer
1449            CMP #&F6
1450            BEQ finished
1451            STA varpointer
1452            INC asc
1453            JMP loop
1454 .finished
1455            LDA #13
1456            JSR &FFE3
1457            LDA #15
1458            JSR &FFE3
1459            RTS
1460 ]
1461 NEXT
1462 ENDPROC
```

Program 3.2. PROCvars – lists all program variables *(cont.)*.

An understanding of variable storage is essential to follow the program's operation. In addition to the resident integer variables there are basically two other types of variable. One of these variables is postfixed with ■ % sign to signify that it is also an integer, while a variable without the % defines that it is a floating point variable. When a program is run, the BASIC interpreter extracts each variable from the program and places it in ■ fixed format above the main program and below TOP. The format is as follows:

(a) A two-byte address which points to the next variable starting with the same letter. If none are present these bytes contain zero.
(b) The variable name in ASCII format excluding the first letter of the variable, e.g. START is stored as TART.
(c) A zero byte to mark the end of the variable name.

(d) The binary representation of the value assigned to that variable. This is stored in four bytes for an integer variable and five bytes for a floating point variable.

We can see from item (a) that it is quite easy to move from one variable to another, starting with the same letter, simply by extracting the address pointer from each variable 'definition' in turn. However, we need to know exactly where the first variable is located and Acorn have provided, by design, a variable pointer table on Page 4 in block zero RAM. Figure 3.3 details the locations holding the pointers for the characters A to Z and a to z. If both locations for a particular character contain zero then no variable beginning with that letter is present.

Character	LSB address	MSB address
A	&482	&483
B	&484	&485
C	&486	&487
D	&488	&489
E	&48A	&48B
F	&48C	&48D
G	&48E	&48F
H	&490	&491
I	&492	&493
J	&494	&495
K	&496	&497
L	&498	&499
M	&49A	&49B
N	&49C	&49D
O	&49E	&49F
P	&4A0	&4A1
Q	&4A2	&4A3
R	&4A4	&4A5
S	&4A6	&4A7
T	&4A8	&4A9
U	&4AA	&4AB
V	&4AC	&4AD
W	&4AE	&4AF
X	&4B0	&4B1
Y	&4B2	&4B3
Z	&4B4	&4B5
a	&4C2	&4C3

Character	LSB address	MSB address
b	&4C4	&4C5
c	&4C6	&4C7
d	&4C8	&4C9
e	&4CA	&4CB
f	&4CC	&4CD
g	&4CE	&4CF
h	&4D0	&4D1
i	&4D2	&4D3
j	&4D4	&4D5
k	&4D6	&4D7
l	&4D8	&4D9
m	&4DA	&4DB
n	&4DC	&4DD
o	&4DE	&4DF
p	&4E0	&4E1
q	&4E2	&4E3
r	&4E4	&4E5
s	&4E6	&4E7
t	&4E8	&4E9
u	&4EA	&4EB
v	&4EC	&4ED
w	&4EE	&4EF
x	&4F0	&4F1
y	&4F2	&4F3
z	&4F4	&4F5

Fig. 3.3. Variable start pointers.

Program lowdown

Figure 3.4 flowcharts the program's operation. The first ten lines of assembler clear the screen, place it into paged mode, save the ASCII code for A in 'asc' and seed the variable pointer table start address, &482, into a zero page vector.

The main program loop is entered at line 1415 and commences by extracting the most significant byte from the pointer table. For a variable to be present, this bye must be non-zero as no variables can be placed in zero page. If it is zero a branch to update is performed, otherwise the low byte address is accessed and seeded into a second vector, pointer.

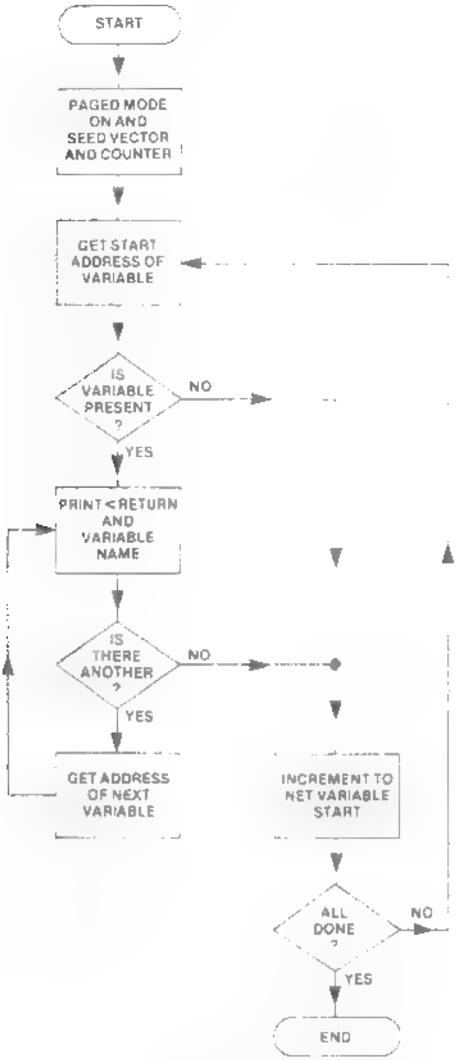


Fig. 3.4. PROCvars flowchart.

Lines 1423 to 1427 print a carriage return followed by the first character of the variable saved in asc. Using post-indexed indirect addressing, the print_loop (lines 1429 to 1434) extract each variable character from the program workspaced, printing each until the zero terminating byte is encountered.

The linking address from the beginning of the variable definition is then sought. If this is zero a branch to update is performed, otherwise the link address is placed into the pointer vector and the next variable name printed.

The update routine (lines 1445 to 1453) first increments the var_pointer vector by two to move onto the next character associated bytes, and increments the character value, asc, by one. The program terminates when the last location in the variable pointer table is reached (line 1449 and 1450). Finally, Figure 3.5 illustrates a typical output of the program, listing the variables in the program itself!

```
asc
addr
end_print
finished
loop
next_var
pass
print_loop
update
varpointer
varstring
variables
```

Fig. 3.5. Typical output produced by Program 3.3.

Program fact sheets

Program 3.1

Procedure title	: PROCinfo
Line numbers	: 1200 to 1352
Variables required	: current.addr
Length	: 372 bytes
Zero page requirements	: 2 bytes (anywhere in memory)
Registers changed	: A, X, Y

Program 3.2

Procedure title	: PROCvars
Line numbers	: 1400 to 1462
Length	: 103 bytes
Zero page requirements	: 5 bytes, four forming vectors
Registers changed	: A, X, Y

Chapter Four
Program Formatters

BASIC's LISTO command allows a limited amount of control in producing formatted listings, inserting spaces to indent loops and structures as required. The two programs presented in this chapter provide an extended formatting option for either BASIC or assembler programs; indeed, the Assembler Formatter was used to produce the clear listing within this book, inserting ten spaces between line number and mnemonic but leaving labels un-indented and clearly separated from the listing.

```
>LIST
   10 REM * A Basic Formatted Listing *
   20 FOR loop=0 TO 100
   30 PRINT loop : NEXT loop
   40 INPUT "A number" N%
   50 IF N%=10 PRINT"Correct" ELSE PRINT
 "wrong"
   60 REPEAT : INPUT "Code" C$
   70 FOR wait=0 TO 1000 : NEXT wait
   80 UNTIL C$="END"


>LIST
   10  REM * A Basic Formatted Listing *
   20  FOR loop=0 TO 100
   30    PRINT loop
       : NEXT loop
   40  INPUT "A number" N%
   50  IF N%=10 PRINT"Correct"
        ELSE PRINT "wrong"
   60  REPEAT
       : INPUT "Code" C$
   70    FOR wait=0 TO 1000
         : NEXT wait
   80    UNTIL C$="END"
```

Fig. 4.1. A BASIC listing with and without the BASIC formatter.

The BASIC formatter splits multistatement lines by issuing a carriage return each time it encounters a colon. It also splits IF...THEN...ELSE structures in addition to indenting them along with REPEAT...UNTIL and FOR...NEXT loops. Figure 4.1 shows the type of listing the BASIC Formatter is capable of. Now for the programs!

The BASIC Formatter (Program 4.1)

The basic_format procedure assembles its machine code into Page 9 of block zero RAM. This area has a number of uses (in addition to housing our machine code) and is more normally associated with ENVELOPEs 5–16, the speech buffer, cassette and RS 423 buffer.

The routine has two entry points – &900 and &928 in this case and function keys 1 and 2 have been programmed to call these locations. These two entries simply turn the formatter on and off respectively.

The 'on' entry point (line 1485) first prints the formatter on message before storing the current value of LISTO, found at &1F, in a byte above the program. Its maximum value of 7 is then inserted. The WRCHV vector contents are extracted and saved and the WRCHV pointed to the 'format' entry point at line 1521. The 'off'

```
   10 REM *** LISTING FORMATTER ***
   20 PROCbasic_format(&900)
   30 *KEY0 CALL &900|M
   40 *KEY1 CALL &928|M
   50 END
   60 :
 1480 DEF PROCbasic_format(addr)
 1481 interpreter=&E0A4
 1482 FOR pass=0 TO 3 STEP3
 1483 P%=addr
 1484 [OPT pass
 1485 .on
 1486                  LDX #&00
 1487 .next_character
 1488                  LDA message,X
 1489                  JSR &FFE3
 1490                  INX
 1491                  CMP#13
 1492                  BNE next_character
 1493                  LDA &1F
 1494                  STA listo
```

Program 4.1. PROCbasic_format – neatly formats a BASIC listing.

```
1495                   LDX #&07
1496                   STX &1F
1497                   LDA &20E
1498                   STA address
1499                   LDA &20F
1500                   STA address+1
1501                   LDA #format MOD 256
1502                   STA &20E
1503                   LDA #format DIV 256
1504                   STA &20F
1505                   RTS
1506 .off
1507                   LDX #&00
1508 .next_character
1509                   LDA message2,X
1510                   JSR &FFE3
1511                   INX
1512                   CMP #13
1513                   BNE next_character
1514                   LDA address
1515                   STA &20E
1516                   LDA address+1
1517                   STA &20F
1518                   LDA listo
1519                   STA &1F
1520                   RTS
1521 .format
1522                   PHA
1523                   CMP #ASC(":")
1524                   BNE no_colon
1525                   JSR output
1526                   LDA #&00
1527                   STA byte
1528                   STA byte+1
1529                   BEQ not_else
1530 .no_colon
1531                   LDA #&01
1532                   CMP &1E
1533                   BNE not_same
1534                   LDA #&00
1535                   STA byte+2
1536                   STA byte+3
1537                   STA byte+4
1538 .not_same
1539                   CPY #&00
1540                   BEQ carry_on
1541 .not_else
1542                   PLA
1543                   JMP interpreter
```

Program 4.1. PROCbasic_format – neatly formats a BASIC listing *(cont.)*.

```
1544 .carry_on
1545                  LDA &37
1546                  CMP #&E7
1547                  BNE not_if
1548                  INC byte+2
1549 .not_if
1550                  CMP #&8B
1551                  BNE not_else
1552                  INC byte+3
1553                  JSR output
1554                  JSR interpreter
1555                  JMP not_else
1556 .output
1557                  LDA #&0A
1558                  JSR interpreter
1559                  LDA #&0D
1560                  JSR interpreter
1561                  CLC
1562                  LDA &3B
1563                  ADC &3C
1564                  ADC byte+2
1565                  TAX
1566                  INX
1567                  LDA #&20
1568                  JSR interpreter
1569                  JSR interpreter
1570                  JSR interpreter
1571 .more_spaces
1572                  JSR interpreter
1573                  JSR interpreter
1574                  DEX
1575                  BNE more_spaces
1576                  RTS
1577 .message
1578                  EQUS" Formatter on!
"
1579                  EQUB 7
1580                  EQUB 13
1581 .message2
1582                  EQUS" Formatter off
!"
1583                  EQUB 7
1584                  EQUB 13
1585 .byte
1586                  EQUS"      "
1587 .address
1588                  EQUS"  "
1589 .listo EQUB 0
1590 ]
1591 NEXT pass
1592 ENDPROC
```

Program 4.1. PROCbasic_format – neatly formats a BASIC listing *(cont.)*.

entry, line 1506, simply reverses these procedures. Line 1518 could be changed if required to make the formatter clear the LISTO option each time it is switched off by replacing it with

```
LDA #0
```

On entry into 'format', through the reset WRCHV the accumulator contains the character to be written. This is tested to see if it is a colon. If this test fails a branch to 'no_colon' is performed. Assuming a colon is present, the 'output' routine at line 1556 is called to perform a line feed and carriage return and a series of spaces printed. The output routine uses a direct jump into the MOS to do the printing. This is necessary as we have intercepted the normal WRCHV address. Incidently, disassembling from this address, &E0A4, provides an interesting insight into how the Beeb programs the CRTC to display characters. As a machine code programmer you must be in possession of a suitable disassembler, so have a look! But I digress, so back to the program description. On return from the output call (line 1526) the 'byte' locations, which act as counters, are cleared and a forced branch to 'not_else' is performed, which prints the character to the screen (line 1541).

Routing around the rest of the code takes place if any of the indenting loop commands already mentioned are identified by intercepting the count value held at &1E and used by LISTO. Special treatment of the IF statement is required to ensure that any subsequent ELSE is generated both on a new line and further indented - this is because ELSE is normally ignored by LISTO. These two commands are identified by their token values before the 'interpreter' call hands them over to the BASIC detokenising routine for expansion. The codes and the entry points are as follows:

IF	(= &E7)	entry at line 1546
ELSE	(= &8B)	entry at line 1550

The byte at &37 is used by the BASIC interpreter to hold the current command token (line 1545).

The Assembler Formatter (Program 4.2)

This utility is probably the one I use most of all along with the global search and replace utility presented in Chapter 7. I find that the neatest way to present assembler listings is in the manner used throughout this book: the mnemonics are indented and clearly

distinguishable from labels, thus making the program easy to read and follow through. The most obvious way to perform this task is simply to tap in spaces as required at the keyboard as the program is entered, but this is boring, time-consuming and extremely wasteful of memory which can be of a premium in the hi-res graphics modes. Thus, Program 4.2 was conceived.

```
  10 REM *** ASSEMBLER FORMATTER ***
  20 PROCass_format (&C00)
  30 *KEY0 CALL &C00:M
  40 *KEY1 CALL &C29:M
  50 END
  60 :
1600 DEF PROCass_format (addr)
1601 oswrch=?&20E+(?&20F*256)
1602 FOR pass=0 TO 3 STEP3
1603 P%=addr
1604 [
1605             OPT pass
1606 .on
1607             LDX #0
1608 .nextchr
1609             LDA message,X
1610             JSR &FFE3
1611             INX
1612             CMP #13
1613             BNE nextchr
1614             LDA#0
1615             STA byte +1
1616             LDA &20E
1617             STA byte+2
1618             LDA &20F
1619             STA byte+3
1620             LDA #assembler MOD 256
1621             STA &20E
1622             LDA #assembler DIV 256
1623             STA &20F
1624             RTS
1625 .off
1626             LDX #0
1627 .nextchr
1628             LDA message2,X
1629             JSR &FFE3
1630             INX
1631             CMP #13
1632             BNE nextchr
1633             LDA byte+2
```

Program 4.2. PROCass_format – makes an assembler listing more readable.

```
1634            STA &20E
1635            LDA byte+3
1636            STA &20F
1637            RTS
1638 .assembler
1639            STA byte
1640            PHP
1641            TXA
1642            PHA
1643            LDA byte+1
1644            BNE testshut
1645            LDA byte
1646            CMP #ASC("[")
1647            BNE return
1648            STA byte+1
1649 .return
1650            LDA byte
1651            JSR oswrch
1652            PLA
1653            TAX
1654            PLP
1655            LDA byte
1656            RTS
1657 .testshut
1658            LDA byte
1659            CMP #93
1660            BNE testcr
1661            LDA#0
1662            STA byte+1
1663            BEQ return
1664 .testcr
1665            CMP #13
1666            BNE testlabel
1667            LDA #0
1668            STA byte+4
1669            BEQ return
1670 .testlabel
1671            CMP #ASC(".")
1672            BEQ signal
1673            CMP #ASC(":")
1674            BCC return
1675            LDA byte+4
1676            BNE return
1677             LDX #10
1678            LDA #32
1679 .spaces
1680            JSR oswrch
1681            DEX
```

Program 4.2. PROCass_format – makes an assembler listing more readable *(cont.)*.

```
1682              BNE spaces
1683              LDA #1
1684 .signal
1685              STA byte+4
1686              JMP return
1687 .message
1688              EQUS"Assembler "
1689              EQUS"Formatter On!"
1690              EQUW &0D07
1691 .message2
1692              EQUS"Assembler "
1693              EQUS"Formatter Off!
1694              EQUW &0D07
1695 .byte
1696              EQUS"     "
1697 ]
1698 NEXT
1699 ENDPROC
```

Program 4.2. PROCass_format - makes an assembler listing more readable *(cont.).*

Like its BASIC predecessor, the Assembler Formatter has two entry points to turn the utility on and off. The 'on' entry point is at line 1606 which outputs the 'Assembler Formatter On' message before saving and redirecting the contents of the WRCHV to the 'assembler' entry point at line 1638. The 'off' routine, entered at line 1625 performs the reverse operation.

When the formatter is on, all output produced by the Beeb is channelled through the 'assembler' routine via WRCHV. After preserving the program status (lines 1639 to 1642) the accumulator's contents are tested to see if they contain the '[' code to indicate the start of assembler (line 1646). If this test succeeds, the code is stored at 'byte+1'. As you may have noticed, the code immediately before this tested this particular location to see if it were non-zero which would denote an already open assembler listing. This test routine would therefore be jumped over to the test_shut routine (line 1657). This section of code first tests to see if the close bracket, end of assembler mark, has been found in which case the 'byte' values are reset and the normal oswrch output pursued.

If a carriage return is not present (lines 1664 to 1669) the 'test_label' routine is invoked. If the label start character, a full-stop, is present the fact is signalled in 'byte+4' and the routine completed; a delimiting colon is treated in a similar manner. If neither of these characters is encountered, the X register is loaded with the number of padding spaces to be printed (line 1677). I chose to use ten though you

can adjust this to your own taste. The 'spaces' loop is entered and exited on completion of printing the ten spaces. Mnemonics will subsequently be printed from this ten spaces in position, while labels are printed as usual.

Program fact sheets

Program 4.1

Procedure title	: PROCbasic_format
Variables required	: addr
Line numbers	: 1480 to 1592
Length	: 227 bytes
Zero page requirements	: none
Registers changed	: none

Program 4.2

Procedure title	: PROCass_format
Variables required	: addr
Line numbers	: 1600 to 1699
Length	: 214 bytes
Zero page requirements	: none
Registers changed	: none

Chapter Five
The Screen

If you are interested in the graphics capabilities of the BBC Micro there will no doubt be occasions when you wish to save the graphics design you have created so that it can be recalled at a later date. Programs 5.1 and 5.2 will facilitate this using the OSFILE call to perform these tasks rapidly in machine code. The third program in this chapter, Program 5.3, provides a printer screen dump program that will work on the Epson, Star and compatible printers.

Save Screen Memory (Program 5.1)

The OSFILE routine is entered in the MOS at &FFDD. Like the majority of the operating system calls it expects to be pointed in the direction of a parameter block via an address held within the index registers. The parameter block needs to contain all the information required by the call to operate. Figure 5.1 details the OSFILE parameter block.

XY+0 to XY+1	:	Filename address. Filename must be terminated by RETURN.
XY+2 to XY+5	:	File load address, stored low byte first.
XY+6 to XY+9	:	Run address of file, stored low byte first.
XY+10 to XY+13	:	Data start address to be saved.
XY+14 to XY+17	:	Data end address.

Fig. 5.1. The OSFILE parameter block.

The OSFILE call can perform up to eight different tasks depending upon the value in the accumulator when the call is effected and these are detailed in Figure 5.2. The call code we are interested in here is with the accumulator holding 0.

0	:	Save block of memory as detailed in parameter block.
1	:	Write information in parameter block to catalogue entry.
2	:	Write load address only for existing file.
3	:	Write the run address only for an existing file.
4	:	Write file attributes only for an existing file.
5	:	Read a file's catalogue information to parameter block.
6	:	Delete file named in parameter block.
255	:	Load the file detailed in the parameter block.

Fig. 5.2. The OSFILE call codes.

Program 5.1 is relatively straightforward, but the amount of screen memory to be saved will vary depending on the currently selected screen mode. For example, MODEs 0,1 and 2 utilise a full 20K from &3000 while MODEs 4 and 5 require 10K from &5800, and the amazingly versatile MODE 7 needs just a meagre 1K from &7C00.

```
  10 REM *** SAVE SCREEN MEMORY ***
  20 PROCsavescreen (&C00)
  30 inc=5
  40 X=640 : Y=512
  50 MODE 4
  60 FOR loop=1 TO 50
  70 MOVE X,Y
  80 DRAW X+inc,Y
  90 DRAW X+inc,Y+inc
 100 DRAW X,Y+inc
 110 DRAW X,Y
 120 X=X-20 : Y=Y-20
 130 inc=inc+40
 140 NEXT
 150 CALL &C00
 160 END
 170 :
1700 DEF PROCsavescreen (addr)
1701 FOR pass=0 TO 3 STEP 3
1702 P%=addr
1703 [
1704           OPT pass
1705 .save_screen
1706           LDA #135
1707           JSR &FFF4
1708           TYA
1709           BEQ dump1
1710           CMP#3
1711           BCC dump1
```

Program 5.1. PROCsavescreen – saves the screen memory to tape or disk.

```
1712             CMP#4
1713             BEQ dump2
1714             CMP#5
1715             BEQ dump2
1716             CMP #7
1717             BEQ teletext
1718 .error
1719             LDY #0
1720 .loop
1721             LDA message,Y
1722             BEQ finished
1723             JSR &FFE3
1724             INY
1725             BNE loop
1726 .finished
1727             RTS
1728 .dump1
1729             LDA #&30
1730             STA paramblk+3
1731             STA paramblk+7
1732             STA paramblk+&0B
1733             LDA #0
1734             JMP osfile
1735 .dump2
1736             LDA #&58
1737             STA paramblk+3
1738             STA paramblk+7
1739             STA paramblk+&0B
1740             LDA#0
1741             JMP osfile
1742 .teletext
1743             LDA #&7C
1744             STA paramblk+3
1745             STA paramblk+7
1746             STA paramblk+&0B
1747             LDA #0
1748             JMP osfile
1749 .osfile
1750             LDX #paramblk MOD 256
1751             LDY #paramblk DIV 256
1752             JMP &FFDD
1753 .filename
1754             EQUS"SSAVED"
1755             EQUB 13
1756 .paramblk
1757             EQUB filename MOD 256
1758             EQUB filename DIV 256
```

Program 5.1. PROCsavescreen – saves the screen memory to tape or disk *(cont.)*.

```
1759              EQUD&3000
1760              EQUD 0
1761              EQUD&3000
1762              EQUD&7FFF
1763 .message
1764              EQUB 7
1765              EQUS"Not a graphics Mode"
1766              EQUB 13
1767              EQUB 0
1768 ]
1769 NEXT
1770 ENDPROC
```

Program 5.1. PROCsavescreen – saves the screen memory to tape or disk *(cont.)*.

The program acts 'intelligently' in this respect by obtaining the current screen mode from the Y register after an *FX135 call (lines 1706 to 1708). If, after the comparison of line 1710, the carry is clear a MODE of less than 3 is indicated and the branch to 'dump1' performed. If a mode value of 4 or 5 is determined, 'dump2' is sought while a branch to 'teletext' is executed if 7 is returned. Note that the 'error' loop is entered if the screen is in MODE 3 or MODE 6; this prints out the 'Not a graphics Mode' message from line 1765 and the routine is exited.

Each of these sections of code simply seed the first page number of the current graphics MODE into the correct places within the parameter block. If the graphics MODE was MODE 1 then the branch to 'dump1' would seed the value &30 into the three bytes at paramblk+3, paramblk+7 and paramblk+&0B, prior to loading the accumulator with 0 and jumping to 'osfile' at line 1749. Here the address of 'paramblk' is loaded into the index registers and a JMP to OSFILE at &FFDD performed.

The parameter block is located at the top of the calling machine code, lines 1756 to 1762 and the EQU functions used to prime the static contents. The filename is stored at 'filename' (line 1753) and I have chosen to use SSAVED, but this can be changed to suit your own needs, of course.

The BASIC test routine simply draws a succession of squares in MODE 4 before using the machine code to save the screen's contents. The following program, Program 5.2, can be used to reload screen memory.

Load Screen Memory (Program 5.2)

The load screen memory program is essentially the same program as its saving counterpart. The main difference is that the accumulator is loaded with 255 to indicate a load operation to the MOS.

```
  10 REM *** LOAD SCREEN MEMORY ***
  20 PROCloadscreen (&C00)
  30 MODE4
  40 CALL &C00
  50 END
  60 :
1800 DEF PROCloadscreen (addr)
1801 FOR pass=0 TO 3 STEP 3
1802 P%=addr
1803 [
1804            OPT pass
1805 .load_screen
1806            LDA #135
1807            JSR &FFF4
1808            TYA
1809            BEQ dump1
1810            CMP#3
1811            BCC dump1
1812            CMP#4
1813            BEQ dump2
1814            CMP#5
1815            BEQ dump2
1816            CMP #7
1817            BEQ teletext
1818 .error
1819            LDY #0
1820 .loop
1821            LDA message,Y
1822            BEQ finished
1823            JSR &FFE3
1824            INY
1825            BNE loop
1826 .finished
1827            RTS
1828 .dump1
1829            LDA #&30
1830            STA paramblk+3
1831            STA paramblk+7
1832            STA paramblk+&0B
1833            LDA #255
1834            JMP osfile
```

Program 5.2. PROCloadscreen – loads a saved graphics screen back into screen memory.

```
1835 .dump2
1836            LDA #&58
1837            STA paramblk+3
1838            STA paramblk+7
1839            STA paramblk+&0B
1840            LDA#255
1841            JMP osfile
1842 .teletext
1843            LDA #&7C
1844            STA paramblk+3
1845            STA paramblk+7
1846            STA paramblk+&0B
1847            LDA #255
1848            JMP osfile
1849 .osfile
1850            LDX #paramblk MOD 256
1851            LDY #paramblk DIV 256
1852            JMP &FFDD
1853 .filename
1854            EQUS"SSAVED"
1855            EQUB 13
1856 .paramblk
1857            EQUB filename MOD 256
1858            EQUB filename DIV 256
1859            EQUD&3000
1860            EQUD 0
1861            EQUD&3000
1862            EQUD&7FFF
1863 .message
1864            EQUB 7
1865            EQUS"Not a graphics Mode"
1866            EQUB 13
1867            EQUB 0
1868 ]
1869 NEXT
1870 ENDPROC
```

Program 5.2. PROCloadscreen – loads a saved graphics screen back into screen memory *(cont.)*.

Printer Screen Dumper

If you own or have aspirations to own a printer then you will certainly wish to be able to dump the contents of screen to the printer at some time to obtain that all important hard copy, be it a graphics masterpiece or just ■ copy of a some neatly formatted data. Program 5.3 was designed specifically for use with 'bit-mapped' printers such

as the Epson and Star ranges. The program is a stand-alone version and includes a short graphics program at the start which will be dumped correctly if you have a suitable printer attached.

```
   10 REM *** PRINTER SCREEN DUMPER ***
   20 REM ***    EPSON FX and STAR  ***
   30 MODE 5
   40 X=640 : Y=512
   50 increment=5
   60 FOR loop=1 TO 50
   70 MOVE X,Y
   80 DRAW X+increment,Y
   90 DRAW X+increment,Y+increment
  100 DRAW X,Y+increment
  110 DRAW X,Y
  120 X=X-20: Y=Y-20
  130 increment=increment+40
  140 NEXT
  150 PROCscreen_dump(&70,&71,&72,&73,&7
5,&76,&2E00)
  160 CALL screen_dump
  170 END
  180 :
 1900 DEFPROCscreen_dump(xlo,xhi,ylo,yhi
,byte,bits,addr)
 1901 FOR pass=0 TO 2 STEP 2
 1902 P%=addr
 1903 [          OPT pass
 1904 .screen_dump
 1905           LDA #2
 1906           JSR &FFEE
 1907           LDA #1
 1908           JSR &FFEE
 1909           LDA #27
 1910           JSR &FFEE
 1911           LDA #1
 1912           JSR &FFEE
 1913           LDA #65
 1914           JSR &FFEE
 1915           LDA #1
 1916           JSR &FFEE
 1917           LDA #8
 1918           JSR &FFEE
 1919           LDA #1
 1920           JSR &FFEE
 1921           LDA #10
 1922           JSR &FFEE
 1923           LDA# &FF
```

Program 5.3. PROCscreen_dump – outputs the graphics screen to a connected printer.

```
1924            STA ylo
1925            LDA# &3
1926            STA yhi
1927 .next_row
1928            LDA# &0
1929            STA xlo
1930            LDA# &0
1931            STA xhi
1932            JSR duel_density
1933            LDA# &1
1934            JSR &FFEE
1935            LDA# &D
1936            JSR &FFEE
1937            SEC
1938            LDA ylo
1939            SBC# 32
1940            STA ylo
1941            BCS check_finish
1942            DEC yhi
1943 .check_finish
1944            LDA yhi
1945            CMP# &FF
1946            BNE next_row
1947            LDA ylo
1948            CMP# &FF
1949            BNE next_row
1950            LDA #1
1951            JSR &FFEE
1952            LDA #12
1953            JSR &FFEE
1954            LDA #1
1955            JSR &FFEE
1956            LDA #27
1957            JSR &FFEE
1958            LDA #1
1959            JSR &FFEE
1960            LDA #64
1961            JSR &FFEE
1962            LDA #3
1963            JSR &FFEE
1964            RTS
1965 .duel_density
1966            LDA# &1
1967            JSR &FFEE
1968            LDA #27
1969            JSR &FFEE
1970            LDA #1
1971            JSR &FFEE
```

Program 5.3. PROCscreen_dump – outputs the graphics screen to a connected printer *(cont.)*.

```
1972          LDA #76
1973          JSR &FFEE
1974          LDA #1
1975          JSR &FFEE
1976          LDA #128
1977          JSR &FFEE
1978          LDA #1
1979          JSR &FFEE
1980          LDA #2
1981          JSR &FFEE
1982 .next_byte
1983          LDA #0
1984          STA bits
1985          LDA #128
1986          STA byte
1987 .read_pixel
1988          LDA #9
1989          LDX #xlo
1990          LDY #0
1991          JSR &FFF1
1992          LDA xlo+4
1993          AND #&FF
1994          BEQ step4
1995          LDA byte
1996          ORA bits
1997          STA bits
1998 .step4
1999          SEC
2000          LDA ylo
2001          SBC #4
2002          STA ylo
2003          BCS rotate
2004          DEC yhi
2005 .rotate
2006          CLC
2007          ROR byte
2008          BCC read_pixel
2009 .print_pattern
2010          LDA #1
2011          JSR &FFEE
2012          LDA bits
2013          JSR &FFEE
2014          CLC
2015          LDA ylo
2016          ADC #32
2017          STA ylo
2018          BCC over
2019          INC yhi
```

Program 5.3. PROCscreen_dump – outputs the graphics screen to a connected printer *(cont.)*.

```
2020 .over
2021            CLC
2022            LDA xlo
2023            ADC #2
2024            STA xlo
2025            BCC leap_frog
2026            INC xhi
2027 .leap_frog
2028            LDA xhi
2029            CMP #5
2030            BNE do_again
2031            RTS
2032 .do_again
2033            JMP next_byte
2034 ]
2035 NEXT pass
2036 ENDPROC
```

Program 5.3. PROCscreen_dump - outputs the graphics screen to a connected printer *(cont.)*.

The machine code of the program assembles just below the memory required by either of the 20K screen modes. It would be a good idea to obtain a second source coding that will sit just below the MODE 4 and 5 memory, thus making the 'unused' screen memory available for use by the program. A suitable value for 'addr' in this instance would be &5600.

The major part of any graphics-printer dump program is spent preparing the pixel - in other words, converting it from its screen form into a form that the printer can handle and translate into selecting which of its eight dot-matrix pins it fires. (Yes, I know there are nine but we only use eight!) The steps required to perform this conversion process are summarised below:

(a) Read a pixel off the screen.
(b) Adjust the byte using suitable rotates.
(c) Check a counter to see if byte is complete.
(d) Adjust the value of Y and X as needed to allow for resolution changes.
(e) Send the byte to the printer in the form of a VDU1 command.

Looking at the assembler program shows that the first section of code from line 1904 to 1926 is responsible for issuing a series of VDU1 codes to the printer using OSWRCH. In BASIC terms the following is performed:

VDU 2, 1, 27, 1, 65, 1, 8, 1, 10

The VDU 2 is used to enable the printer while the intermediate codes set the line spacing to $\frac{8}{72}$ inches. The final VDU 10 performs a line feed. Much of the code comprises these VDU1 codes and they could be more efficiently incorporated into a look-up table if required. I have persevered with the long-winded method mainly for reasons of clarity.

Lines 1922 to 1932 initialise the variables ylo, yhi and xlo, xhi. The pair ylo,yhi are loaded with &3FF which in decimal is 1023 and shows itself to be the maximum on-screen value of the Y axis. The xlo,xhi combination are set to zero. The 'dual_density' subroutine is responsible for putting the printer in graphics gear and performs a BASIC VDU 1, 27, 1, 76, 1, 128, 2 selecting 640 dots per line in bit image mode.

Before printing, the current screen pixel details must be read from the screen. This is readily performed with OSWORD and the accumulator holding 9 (lines 1987 to 1992). The parameter block requires five bytes set out as follows using the declared variables:

xlo	low byte X coordinate
xhi	high byte X coordinate
ylo	low byte Y coordinate
yhi	high byte Y coordinate
xlo+4	result after OSWORD call

As can be seen, we have neatly used the program variables to form the parameter block of the call, a saving in coding and space when it works!

The byte to be sent to the printer is formed by rotating it through the carry flag position into the accumulator (lines 2003 to 2013) and printing it via OSWRCH. The rest of the general housekeeping is performed in lines up to 2033 and the whole process repeated until the 'check_finish' (line 1943) routine indicates a completed picture. The final succession of VDU 1 calls issue a form feed, place the printer into its more standard printing mode and disenable it. Figure 5.3 shows a dump produced by the program on my own printer.

One final point: always ensure that the graphics origin is set to its normal default position prior to calling the dump. This is best done by inserting a VDU 29,0;0; at the onset of the program. As it stands, the program looks at every screen coordinate: if any of these have been moved off the screen due to a redefined graphics origin then the pixel read routine will return −1 or &FF, which will cause awful black bars and lines to be printed as part of your dump in the offscreen areas.

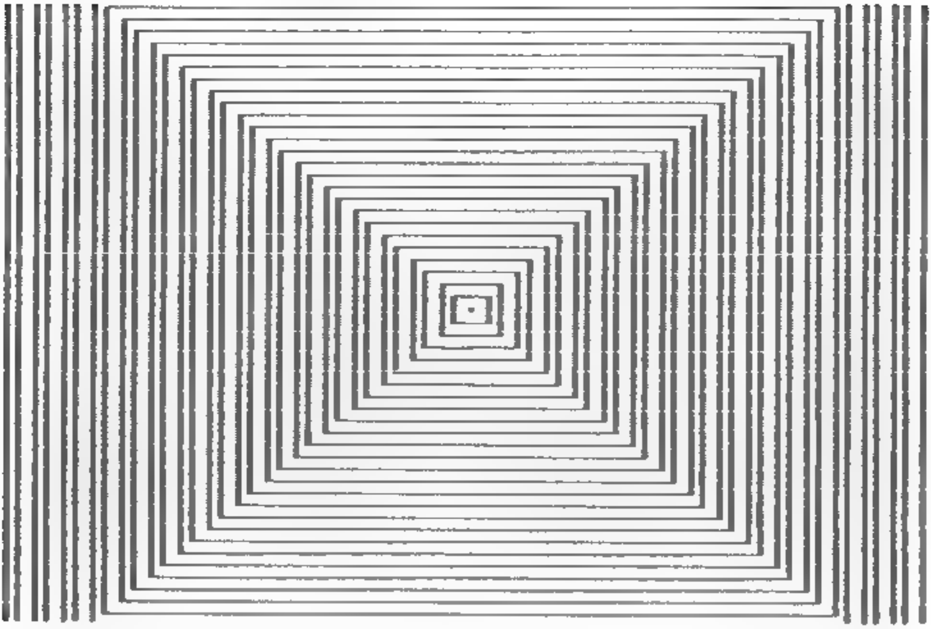


Fig. 5.3. Screen dump produced by Program 5.3.

Program fact sheets

Program 5.1

Procedure title	:	PROCsavescreen
Variables required	:	addr
Line numbers	:	1700 to 1770
Length	:	140 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 5.2

Procedure title	:	PROCloadscreen
Variables required	:	addr
Line numbers	:	1800 to 1870
Zero page requirements	:	none
Registers changed	:	A,X,Y

Program 5.3

Procedure title	:	PROCscreen_dump
Variables required	:	xlo, xhi, ylo, yhi, byte, bits, addr
Line numbers	:	1900 to 2036
Program length	:	260 bytes
Zero page requirements	:	7 bytes
Registers changed	:	A, X, Y

Chapter Six
Softly, Softly

The Beeb allows the user to define characters using the VDU 23 command. This is followed by eight byte-sized numbers which represent the bit patterns of the eight bytes that form the character.

```
*** SOFT CHR CHARACTER DEFINITIONS ***

224:  32,165, 12,169,224,133,114,169,
225:  12,133,113,169,  0,133,112,133,
226: 115,133,116,168, 32,148, 12,165,
227: 115,208, 12,165,116,208,  8, 32,
228: 227, 12,208,240, 76,239, 12,165,
229: 114, 32, 89, 12,169, 58, 32,238,
230: 255,169, 32, 32,238,255,160,  0,
231: 177,112, 32, 89, 12,169, 44, 32,
232: 238,255,200,192,  8,208,241, 32,
233: 227, 12,169,  0,133,115,133,116,
234: 168,169, 13, 32,227,255, 76, 20,
235:  12,162,  0,134,117,201,100,144,
236:   8,233,100,232,134,117, 76, 93,
237:  12, 32,129, 12,162,  0,201, 10,
238: 144,  6,233, 10,232, 76,110, 12,
239:  32,129, 12, 24,105, 48, 76,238,
240: 255, 72,138,105, 48,201, 48,208,
241:   6,166,117,208,  2,169, 32, 32,
242: 238,255,104, 96,160,  7,177,112,
243:  24,101,115,133,115,144,  2,230,
244: 116,136, 16,242, 96,162,  0,189,
245: 180, 12, 48,  7, 32,238,255,232,
246:  76,167, 12, 96, 10, 13, 10, 13,
247:  42, 42, 42, 32, 83, 79, 70, 84,
248:  32, 67, 72, 82, 32, 67, 72, 65,
249:  82, 65, 67, 84, 69, 82, 32, 68,
250:  69, 70, 73, 78, 73, 84, 73, 79,
251:  78, 83, 32, 42, 42, 42, 10, 13,
252:  10, 13,255, 24,165,112,105,  8,
253: 133,112,230,114,240,  1, 96, 32,
254: 231,255,104,104, 96,  0,  0,  0,
```

Fig. 6.1. A typical output produced by PROCvduchrs.

Primarily these definable characters, 224 to 255, are used to create new characters whether they be fancy stylised alphanumeric characters or, more commonly, games characters. Program 6.1 provides a routine that will display the full definitions of any of these characters that have been defined. Figure 6.1 shows the output produced by the program.

User-definable characters are stored in the soft character definition area on page &C between &C00 to &CFF. Machine code programmers will know this area better as an assembly area for their code! As mentioned, eight bytes are associated with each character; thus, character VDU 224 is allocated the eight bytes &C00 to &C07 inclusive; VDU 225 the bytes &C08 to &C0F, and on up to VDU 255 which is allocated the bytes &CF8 to &CFF. The first byte in each definition (the top-most one) is placed in the first byte of the corresponding memory location and so on — as Figure 6.2 illustrates.

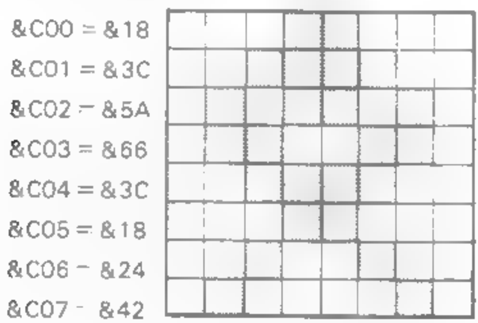


Fig. 6.2. The byte definition storage of user-defined character 224.

As Figure 6.1 showed, the program does not print out the contents of every character — merely the characters that are or seem to be defined. This is quite simple to determine. On a power-up or reset, the MOS clears this area of memory with zero, so all the program needs to do is to add up the bytes corresponding to each VDU character. If the result is zero, no definition is present and the next character is sought. If, on the other hand, the result is non-zero then a definition is assumed and the contents printed. I say 'assumed' because it might not be a proper definition — it may, of course, be machine code! Also, the last 5 characters in the buffer, VDU 250 to VDU 255, seem to be susceptible to having garbage placed into them by the MOS.

Figure 6.3 flowcharts the program's operation. The definition test just discussed is performed by the 'test_for_definition' routine (lines 2135 to 2147 in Program 6.1). The result of the summing is placed in the 'addition'

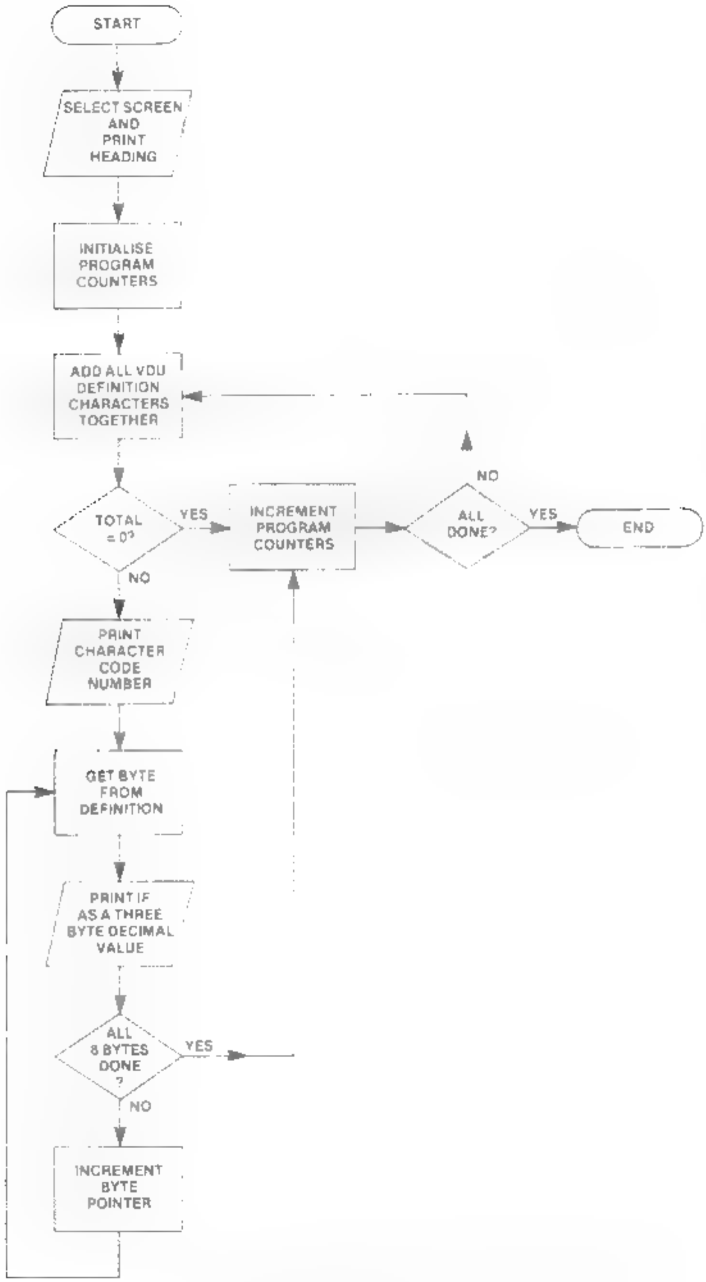


Fig. 6.3. The PROCvduchr flowchart.

bytes which are tested in the main program loop. If either are non-zero then a branch to 'print_definition' is executed (lines 2067 to 2070).

The 'print_definition' loop (lines 2074 to 2097 in Program 6.1)

begins by printing the VDU number of the current character followed by a colon. Each byte is then extracted in turn and printed to the screen in decimal form followed by a comma. After the last definition byte is printed a new line is printed and the next VDU character is sought. The 'update routine' (lines 2166 to 2173), as its name implies, increments all program counters and determines when every VDU character has been processed.

```
   10 REM * SOFT CHR VDU'S VERSION V2 *
   20 REM *(c) Bruce Smith/Acorn User *
   30 PROCvdhchr(&70,&72,&73,&75,&4000)
   40 *KEY0 CALL &4000:M
   50 END
   60 :
 2050 DEF PROCvdhchr(soft_base,vdu_char
acter,addition_bytes,flag,addr)
 2051 FOR pass=0 TO 3 STEP3
 2052 P%=&4000
 2053 [           OPT pass
 2054 .start
 2055           JSR set_up_screen
 2056           LDA #224
 2057           STA vdu_character
 2058           LDA #&C
 2059           STA soft_base+1
 2060           LDA #0
 2061           STA soft_base
 2062           STA addition_bytes
 2063           STA addition_bytes+1
 2064           TAY
 2065 .main_loop
 2066           JSR test_for_definition
 2067           LDA addition_bytes
 2068           BNE print_definition
 2069           LDA addition_bytes+1
 2070           BNE print_definition
 2071           JSR update
 2072           BNE main_loop
 2073           JMP exit
 2074 .print_definition
 2075           LDA vdu_character
 2076           JSR binary_decimal_print
 2077           LDA #ASC":"
 2078           JSR &FFEE
 2079           LDA #ASC" "
 2080           JSR &FFEE
 2081           LDY #0
 2082 .loop
```

Program 6.1. PROCvduchrs – lists the soft character definitions.

```
2083            LDA (&70),Y
2084            JSR binary_decimal_print
2085            LDA #ASC","
2086            JSR &FFEE
2087            INY
2088            CPY #8
2089            BNE loop
2090            JSR update
2091            LDA#0
2092            STA addition_bytes
2093            STA addition_bytes+1
2094            TAY
2095            LDA #13
2096            JSR &FFE3
2097            JMP main_loop
2098  .binary_decimal_print
2099            LDX #0
2100            STX flag
2101  .hundreds
2102            CMP#100
2103            BCC no_hundreds
2104            SBC #100
2105            INX
2106            STX flag
2107            JMP hundreds
2108  .no_hundreds
2109            JSR print_decimal
2110            LDX #0
2111  .tens
2112            CMP #10
2113            BCC no_tens
2114            SBC #10
2115            INX
2116            JMP tens
2117  .no_tens
2118            JSR print_decimal
2119            CLC
2120            ADC #ASC"0"
2121            JMP &FFEE
2122  .print_decimal
2123            PHA
2124            TXA
2125            ADC #ASC"0"
2126            CMP #ASC"0"
2127            BNE no_zero
2128            LDX flag
2129            BNE no_zero
2130            LDA #32
```

Program 6.1. PROCvduchrs – lists the soft character definitions *(cont.)*.

```
2131  .no_zero
2132            JSR &FFEE
2133            PLA
2134            RTS
2135  .test_for_definition
2136            LDY#7
2137  .check_loop
2138            LDA (&70),Y
2139            CLC
2140            ADC addition_bytes
2141            STA addition_bytes
2142            BCC no_carry
2143            INC addition_bytes+1
2144  .no_carry
2145            DEY
2146            BPL check_loop
2147            RTS
2148  .set_up_screen
2149            LDX#0
2150  .next_character
2151            LDA table,X
2152            BMI done
2153            JSR &FFEE
2154            INX
2155            JMP next_character
2156  .done
2157            RTS
2158  .table
2159            EQUB 22
2160            EQUB 6
2161            EQUD &0D0A0D0A
2162            EQUS"*** SOFT CHR"
2163            EQUS" CHARACTER "
2164            EQUS"DEFINITIONS ***"
2165            EQUD &0D0A0D0A
2166            EQUB 255
2167  .update
2168            CLC
2169            LDA soft_base
2170            ADC#8
2171            STA soft_base
2172            INC vdu_character
2173            BEQ exit
2174            RTS
2175  .exit
2176            JSR &FFE7
2177            PLA
2178            PLA
```

Program 6.1. PROCvduchrs – lists the soft character definitions *(cont.)*.

```
2179              RTS
2180  ]
2181  NEXT pass
2182  ENDPROC
```

Program 6.1. PROCvduchrs – lists the soft character definitions *(cont.)*.

The program incorporates a useful decimal printing routine between lines 2098 and 2134. This itself would be useful to have as a separate procedure. Character base conversion can seem difficult, but like most things in life it is quite simple to do when you know how!

As it stands, the routine will convert an eight-bit binary number held in the accumulator into a three-digit decimal ASCII number, or more correctly a string of three ASCII characters. Thus, if the accumulator held 11110001 (&F1) the ASCII string "241" would be printed.

To perform this, it is first necessary to calculate how many hundreds, tens and units there are in the byte. All that is required to do this is to subtract 100 or 10 from the byte and increment a hundreds or tens count each time the subtraction leaves a remainder. Using the byte &E1 mentioned above this would work as follows. First, the hundreds:

```
  241
 −100
 ----
  141    hundreds count=1
 ----

  141
 −100
 ----
   41    hundreds count=2
 ----

   41
 −100
 ----
  −59    This result is negative
 ----
```

The final hundreds count is therefore 2. This can be converted into its ASCII code simply by adding ASC"0" and printing it.

Next, the tens count, and the value we use to start with is the remainder from the hundreds count.

```
 41
-10
---
 31    tens count = 1
---
 31
-10
---
 21    tens count = 2
---
 21
-10
---
 11    tens count = 3
---
 11
-10
---
  1    tens count = 4
---
```

The final tens count is therefore 4, and adding ASC"0" to this will derive the ASCII code for 4 which can be printed. Finally, the units count is left as the remainder, 1 in this case. Again, ASC"0" needs to be added to this to get the character's ASCII code so that it can be printed.

Program fact sheet

Program 6.1

Procedure title	:	PROCvduchr
Variables Required	:	soft_base, vdu_character, addition_bytes, flag, addr
Line numbers	:	2050 to 2181
Length	:	246 bytes
Zero page requirements	:	6 bytes
Registers changed	:	A, X, Y

Chapter Seven

Global Variable Search and Replace

GREPL is the longest program in this book, a massive 582 bytes when assembled, but it is invaluable. Using it allows variable names within a program to be replaced throughout simply and easily. This eradicates the need to work through the program replacing them 'by hand', thus allowing new, more meaningful, names to be assigned or, if memory is tight, shorter names to be inserted.

Program Description

Because of the long nature of the program, I have chosen to present the program details in a line-by-line block format which if used in conjunction with the flowchart of Figure 7.1 and the description of variable storage in Chapter 3 should make its understanding much easier.

Line 2195: Clear occurrence counter.
Lines 2196 to 2198: Print 'variable' prompt.
Lines 2199 to 2202: Input variable name to be replaced into buffer, pointed to by the Index registers and save the strings length in 'olen'.
Lines 2203 to 2205: Print 'Replace with' prompt.
Lines 2206 to 2208: Input new variable name and store it in buffer pointed to by the Index registers.
Lines 2210 to 2213: Calculate difference in variable name lengths and save result.
Lines 2214 to 2217: Read current setting of OSHWM.
Lines 2219 to 2221: Clear registers and get first byte from program.
Lines 2222 to 2227: If byte is ASCII return, check for the TOP marker &FF.
Lines 2228 to 2230: If TOP found perform OSNEWL and exit via 'report'.

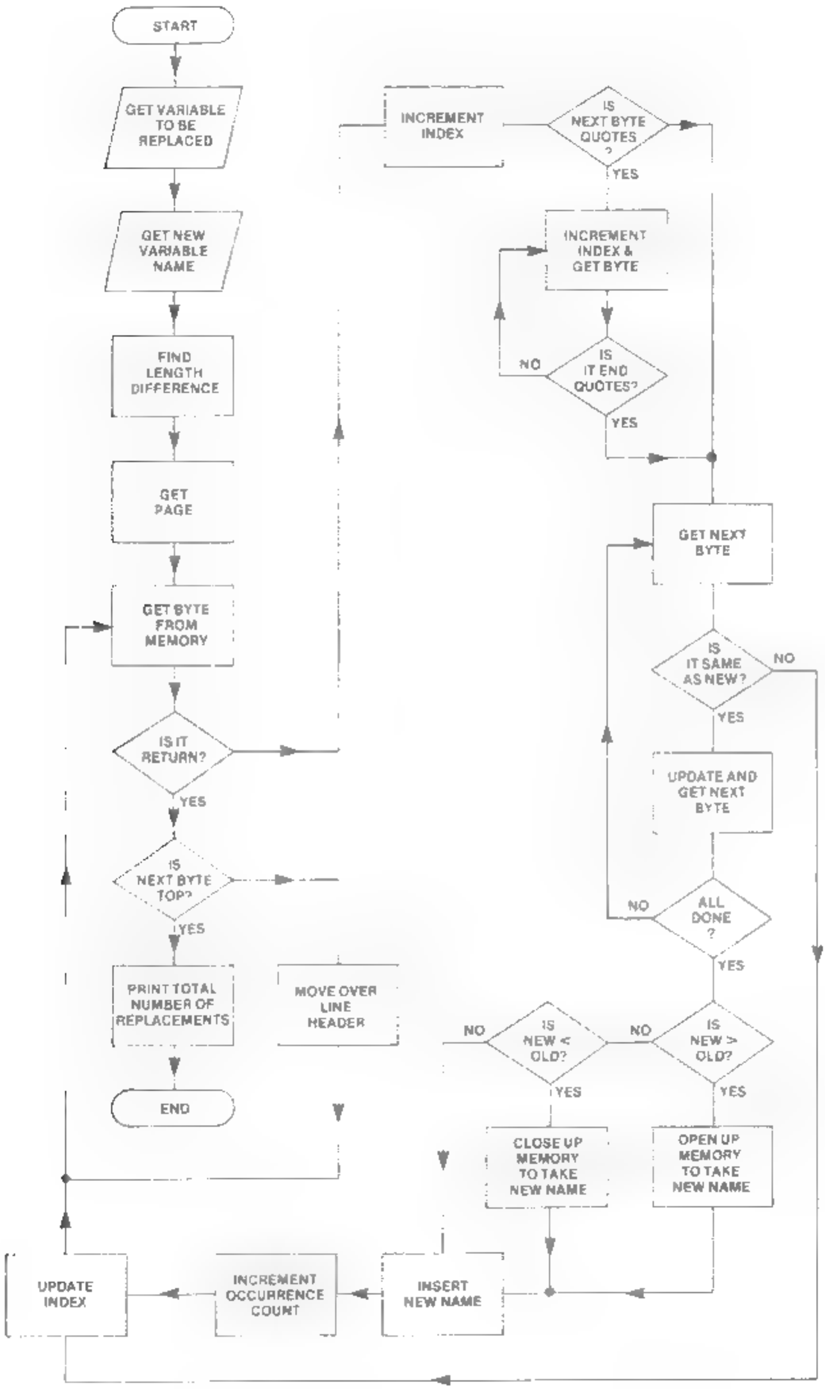


Fig. 7.1. Flowchart for PROCgrepl.

```
   10 REM ***GLOBAL REPLACE - GREPL***
   20 himem=HIMEM
   30 himem=himem-&300
   40 HIMEM=himem
   50 PROCgrepl (&70,&72,&74,&76,&77,&78
,himem)
   60 *KEY0 CALL HIMEM!M
   70 END
   80 :
 2190 DEF PROCgrepl (current,last,link,o
len,nlen,result,himem)
 2191 FOR pass=0 TO 3 STEP 3
 2192 P%=HIMEM
 2193 [OPT pass
 2194 .Global_replace
 2195 LDA #0 :STA number
 2196 LDX #old_prompt MOD 256
 2197 LDY #old_prompt DIV 256
 2198 JSR print_string
 2199 LDX #old_name_store MOD 256
 2200 LDY #old_name_store DIV 256
 2201 JSR input_string
 2202 STA olen
 2203 LDX #new_prompt MOD 256
 2204 LDY #new_prompt DIV 256
 2205 JSR print_string
 2206 LDX #new_name_store MOD 256
 2207 LDY #new_name_store DIV 256
 2208 JSR input_string
 2209 .do_again
 2210 SEC
 2211 STA nlen
 2212 SBC olen
 2213 STA result
 2214 LDA #&83
 2215 JSR &FFF4
 2216 STX current
 2217 STY current+1
 2218 .main_loop
 2219 LDX #0
 2220 TXA :TAY
 2221 LDA (current),Y
 2222 CMP #13
 2223 BNE not_return
 2224 INY
 2225 LDA (current),Y
 2226 CMP #&FF
 2227 BNE over
```

Program 7.1. PROCgrepl - a global search and replace facility.

```
2228 JSR &FFE7
2229 LDA number
2230 JMP report
2231 RTS
2232 .over
2233 CLC
2234 LDA current
2235 ADC #3
2236 STA link
2237 LDA current+1
2238 ADC #0
2239 STA link+1
2240 LDY #4
2241 BNE update4
2242 .not_return
2243 CMP #&22
2244 BNE validity_test
2245 .end_quotes
2246 INY
2247 LDA (current),Y
2248 CMP #&22
2249 BEQ update3
2250 CMP #13
2251 BNE end_quotes
2252 BEQ update4
2253 .validity_test
2254 CMP #ASC"&"
2255 BEQ hexadecimal
2256 JSR check_variable
2257 BCC match_names
2258 .hexadecimal
2259 INY
2260 LDA (current),Y
2261 JMP validity_test
2262
2263 .match_names
2264 CPY olen
2265 BNE update2
2266 DEY
2267 .next_chr
2268 LDA (current),Y
2269 CMP old_name_store,Y
2270 BNE move_on
2271 DEY
2272 BPL next_chr
2273 BMI insert_new
2274 .move_on
2275 LDY olen
```

Program 7.1. PROCgrepl – a global search and replace facility *(cont.)*.

```
2276 .update2
2277 TYA
2278 BNE update4
2279 .update3
2280 INY
2281 .update4
2282 JSR memory_update
2283 DEY
2284 BNE update4
2285 BEQ main_loop
2286 .insert_new
2287 INC number
2288 LDA current
2289 STA last
2290 LDA current+1
2291 STA last+1
2292 LDY #0
2293 CLC
2294 LDA result
2295 ADC (link),Y
2296 CMP #238
2297 BCC leap_frog
2298 JMP bad_string
2299 .leap_frog
2300 LDX #2
2301 STA (link),Y
2302 LDA result
2303 BEQ overwrite
2304 BMI shuffle_down
2305 .back
2306 JSR memory_update
2307 LDA (last),Y
2308 CMP #&FF
2309 BNE back
2310 LDX #0
2311 LDY result
2312 .shuffle_up
2313 LDA (last,X)
2314 STA (last),Y
2315 LDA last
2316 BNE low_last
2317 DEC last+1
2318 .low_last
2319 DEC last
2320 LDA last
2321 CMP current
2322 BNE shuffle_up
2323 LDA last+1
```

Program 7.1. PROCgrepl – a global search and replace facility *(cont.)*.

```
2324 CMP current+1
2325 BNE shuffle_up
2326 .overwrite
2327 LDY #0
2328 .inset_loop
2329 LDA new_name_store,Y
2330 STA (current),Y
2331 INY :CPY nlen
2332 BNE inset_loop
2333 LDX #0
2334 BEQ update2
2335 .shuffle_down
2336 LDA result
2337 EOR #&FF
2338 TAY
2339 INY
2340 .next_down
2341 LDA (last),Y
2342 STA (last-2,X)
2343 JSR memory_update
2344 CMP #&FF
2345 BNE next_down
2346 BEQ overwrite
2347 .memory_update
2348 INC current,X
2349 BNE skip_high
2350 INC current+1,X
2351 .skip_high
2352 RTS
2353 .check_variable
2354 CMP #ASC"z"+1
2355 BCS less_than
2356 CMP #ASC"_"
2357 BCS greater_than
2358 CMP #ASC"Z"+1
2359 BCS less_than
2360 CMP #ASC"A"
2361 BCS greater_than
2362 CMP #ASC"$"
2363 BEQ greater_than
2364 CPY #0
2365 BEQ less_than
2366 CMP #ASC"9"+1
2367 BCS less_than
2368 CMP #ASC"0"
2369 BCS greater_than
2370 CMP #ASC"%"
2371 BEQ greater_than
```

Program 7.1. PROCgrepl – a global search and replace facility *(cont.)*.

```
2372 .less_than
2373 CLC
2374 .greater_than
2375 RTS
2376 .print_string
2377 STX current
2378 STY current+1
2379 LDY #0
2380 .print_string2
2381 LDA (current),Y
2382 BMI no_more
2383 JSR &FFE3
2384 INY
2385 BNE print_string2
2386 .no_more
2387 RTS
2388 .input_string
2389 STX last
2390 STY last+1
2391 .input_loop2
2392 LDY #0
2393 .get_character
2394 JSR &FFE0
2395 CMP #&1B
2396 BEQ escape
2397 CMP #13
2398 BEQ string_end
2399 CMP #&7F
2400 BEQ rub_out
2401 JSR check_variable
2402 BCC get_character
2403 STA (last),Y
2404 JSR &FFE3
2405 .input_loop3
2406 INY
2407 CPY #21
2408 BEQ too_big
2409 BNE get_character
2410 .string_end
2411 TYA
2412 BEQ get_character
2413 JSR &FFE7
2414 TYA
2415 RTS
2416 .rub_out
2417 DEY
2418 BMI input_loop3
2419 JSR &FFE3
```

Program 7.1. PROCgrepl - a global search and replace facility *(cont.)*.

```
2420 JMP get_character
2421 .too_big
2422 LDX #error1 MOD 256
2423 LDY #error1 DIV 256
2424 JSR print_string
2425 PLA :PLA :RTS
2426 .escape
2427 LDA #&7E
2428 JSR &FFF4
2429 PLA :PLA :RTS
2430 .report
2431 LDX #0
2432 SEC
2433 .decimal_loop
2434 SBC #10
2435 BMI no_jump
2436 INX
2437 JMP decimal_loop
2438 .no_jump
2439 DEX
2440 CLC
2441 ADC #59
2442 PHA
2443 TXA
2444 ADC #48
2445 CMP #ASC"0"
2446 BEQ no_print
2447 JSR &FFEE
2448 .no_print
2449 PLA
2450 JSR &FFEE
2451 LDX #done MOD 256
2452 LDY #done DIV 256
2453 JMP print_string
2454 .bad_string
2455 LDX #error2 MOD 256
2456 LDY #error2 DIV 256
2457 JSR print_string
2458 LDX #20
2459 .swap_pointers
2460 LDA old_name_store,X
2461 PHA
2462 LDA new_name_store,X
2463 STA old_name_store,X
2464 PLA
2465 STA new_name_store,X
2466 DEX
2467 BPL swap_pointers
```

Program 7.1. PROCgrepl – a global search and replace facility *(cont.)*.

```
2468 LDA olen
2469 PHA
2470 LDA nlen
2471 STA olen
2472 PLA :PLA :PLA
2473 RTS
2474 .old_name_store
2475 EQUS"                       "
2476 .new_name_store
2477 EQUS"                       "
2478 .old_prompt
2479 EQUB 13
2480 EQUS"Variable : "
2481 EQUB 255
2482 .new_prompt
2483 EQUB 13
2484 EQUS"Replace with :"
2485 EQUB 255
2486 .error1
2487 EQUB 13
2488 EQUS"Err1"
2489 EQUW &FF07
2490 .error2
2491 EQUB 13
2492 EQUS"Err2"
2493 EQUW &FF07
2494 .done
2495 EQUS" occurrence(s) replaced"
2496 EQUW &FF0D
2497 .number EQUB 0
2498 ] :NEXT pass
2499 ENDPROC
>
```

Program 7.1 PROCgrepl – a global search and replace facility *(cont.)*.

Lines 2233 to 2241: Otherwise move on past new line header bytes and force branch to 'update4'.
Lines 2243 to 2244: Test for quotes and branch if not there.
Lines 2245 to 2249: Locate the end pair of quotes.
Lines 2250 to 2252: If ASCII return found first, branch to 'update4'.
Lines 2254 to 2255: If a hexadecimal value is indicated, branch.
Lines 2256 to 2261: Check for a valid variable character.
Lines 2263 to 2272: Compare old variable name with the string pointed to in the program by 'current'. Exit on first unlike character.
Line 2273: If negative strings compared force a branch to 'insert_new'.

Lines 2274 to 2285: String not found so update all pointers and redo from 'main_loop'.
Lines 2286 to 2291: Increment occurrence pointer and update pointers.
Lines 2292 to 2298: Add new line length to the 'link' byte. If link byte is greater than permissible value then perform 'bad_string' error. Else go to 'leap_frog'.
Lines 2299 to 2304: Calculate if space occupied by variable needs to be altered, if so, move distal portion of program up or down memory as required.
Lines 2305 to 2325: Open up the program at the variable name to make way for a longer variable name.
Lines 2326 to 2334: Write new variable name over the old variable name.
Lines 2335 to 2346: Close up variable space by desired amount to ensure that new shorter variable name fits correctly, then overwrite it.
Lines 2347 to 2352: Update current position in program vector.
Lines 2353 to 2375: Check that 'current' contents being investigated is a legal variable value.
Lines 2376 to 2387: Print the ASCII character string pointed to by the address held in the Index registers. Printing is terminated on encountering a negative byte, typically &FF.
Lines 2388 to 2415: Input an ASCII character string up to 20 characters long and store it in the buffer pointed to by the index registers.
Lines 2416 to 2420: Perform DELETE.
Lines 2421 to 2425: Execute 'Too big' error.
Lines 2426 to 2429: Handle ESCAPE.
Lines 2430 to 2453: Print number of occurrences after first converting it into an ASCII-based decimal number.
Lines 2454 to 2457: Print bad string error message.
Lines 2458 to 2473: Reset pointers to former values and exit to BASIC.
Lines 2474 to 2497: ASCII string storage area.

Using GREPL

Because of its large size, a hole must be created within the Beeb's memory map to insert GREPL, because the normal page size areas are not big enough. The program makes a niche by lowering

HIMEM by three pages and placing it above the new value, programming function key 0 with the correct call address.

To use GREPL press f0 and answer to the prompts as they appear. The new variable name may be up to 20 characters long; variables greater than this are not accepted. Once the replace name is entered the program goes about its business and the number of occurrences/replacements are indicated on completion.

Program fact sheet

Program 7.1

Procedure title	:	PROCgrepl
Variables required	:	current, last, link, olen, nlen, result, himem
Line numbers	:	2190 to 2499
Length	:	582 bytes
Zero page requirements	:	9 bytes
Registers changed	:	A, X, Y

Chapter Eight
Time for Bed

Next to Saturday night's *Match of the Day*, the home computer must be the most frequent centrepiece of the friendly matrimonial dispute. Even four years on, my wife will often appear in the early hours of the morning to 'pull the plug out' of my latest sojourn into the land of ROM and RAM. It is certain that most hobbyists world-wide have suffered their mate's wrath in the small hours of the night at some time. It is difficult to explain to the non-committed that, once in front of the keyboard, time is meaningless.

This program was born at the specific request of my wife. It's a background clock that sits ticking its digits away at the top right-hand corner of the screen while the Beeb goes about its more important tasks, stopping once every second to create the tick or tock to push the second-hand a fraction further into the night!

The clock is based on the use of events or, more correctly, the redirection of events. The BBC Micro is built up around events, so much so that all the time it is switched on and being used it actually stops what it is doing every ten milliseconds to catch up on any outstanding house-keeping chores it needs to be. These chores take many guises and range from reading any pressed keys into the keyboard buffer to sampling some of the ADC channels. Due to the design of the BBC Micro it is possible to intercept these events as they take place and interpret them as we wish, and this concept forms the basis of the digital clock display.

There are several ways in which an event can be made to occur and these are listed in Figure 8.1. The one that we are particularly interested in is event 5 which occurs when the interval timer crosses zero. The interval timer is a 5-byte clock that is incremented one hundred times every second. When the timer is incremented so that it resets to zero, i.e. goes from &FFFFFFFFFF to &0, the event is initiated. When the event occurs, the operating system is directed through the event vector, EVNTV at &220, so that by redirecting this

Event	Cause
0	Output buffer empty
1	Input buffer full
2	Character for input buffer entering
3	ADC conversion finished
4	Vertical sync start
5	Interval timer crossing zero
6	ESCAPE detected
7	RS 423 error
8	Econet event detected
9	User event detected

Fig. 8.1 Details of operating system events.

vector to our own event handler the appropriate action can be taken.

The basic component in our clock is, of course, the second, so the interval timer must be made to time-out every second. Being an up-counting device, the interval timer must be loaded with −100 centiseconds. This write interval timer operation is performed using an OSWORD 4 call. As with all OSWORD calls the index registers hold the address of the parameter block which contains the 5-byte value to be written. In Program 8.1, the parameter block is located at 'clock' lines 2606 to 2608.

```
   10  REM *** Continuous display clock
***
   20  REM *** redirects EVENTV vector
***
   30  *FX13,5
   40  CLS
   50  PRINTCHR$141;" - The Mute Clock!"

   60  PRINTCHR$141;"   The Mute Clock!"
'''
   70  INPUT"Hour     :"H%
   80  INPUT"Minute   :"M%
   90  INPUT"Seconds  :"S%
  100  PROCtime(H%,M%,S%,&A00)
  110  PRINT''
  120  PRINT"You have set the time for:"
;
  130  PRINT"   ";H%;":";M%;":";S%''
```

Program 8.1. PROCtime – a background digital clock.

```
  140  PRINT"Press key to start clock"
  150  key=GET
  160  CALL &A00
  170  END
  180  :
 2500  DEF PROCtime(gethrs,getmins,getse
cs,addr)
 2501  FOR pass=0 TO 2 STEP 2
 2502  P%=addr
 2503  [OPT pass
 2504                 JMP setup
 2505  .tick_tock
 2506                 PHP
 2507                 PHA
 2508                 PHA
 2509                 TYA
 2510                 PHA
 2511                 LDA#4
 2512                 LDY#clock DIV 256
 2513                 LDX#clock MOD 256
 2514                 JSR &FFF1
 2515                 INC seconds
 2516                 LDA seconds
 2517                 CMP#60
 2518                 BNE over
 2519                 LDA#0
 2520                 STA seconds
 2521                 INC minutes
 2522                 LDA minutes
 2523                 CMP#60
 2524                 BNE over
 2525                 LDA#0
 2526                 STA minutes
 2527                 INC hours
 2528                 LDA hours
 2529                 CMP#24
 2530                 BNE over
 2531                 LDA#0
 2532                 STA hours
 2533  .over
 2534                 LDA hours
 2535                 LDY#72
 2536                 JSR display
 2537                 LDA#ASC":"
 2538                 STA HIMEM,Y
 2539                 INY
 2540                 LDA minutes
 2541                 JSR display
```

Program 8.1. PROCtime – a background digital clock *(cont.)*.

```
2542              LDA#ASC":"
2543              STA HIMEM,Y
2544              INY
2545              LDA seconds
2546              JSR display
2547              PLA
2548              TAY
2549              PLA
2550              TAX
2551              PLA
2552              PLP
2553              RTS
2554  .display
2555              LDX#0
2556              SEC
2557  .loop
2558              SBC#10
2559              BMI no_jump
2560              INX
2561              JMP loop
2562  .no_jump
2563              DEX
2564              CLC
2565              ADC#58
2566              PHA
2567              TXA
2568              ADC#48
2569              STA HIMEM,Y
2570              INY
2571              PLA
2572              STA HIMEM,Y
2573              INY
2574              RTS
2575
2576  .setup
2577              LDA #gethrs
2578              LDX #getmins
2579              LDY #getsecs
2580              STA hours
2581              STX minutes
2582              STY seconds
2583               LDA#22
2584              JSR &FFEE
2585              LDA#7
2586              JSR &FFEE
2587              LDA#28
2588              JSR &FFEE
2589              LDA#0
```

Program 8.1. PROCtime – a background digital clock *(cont.)*.

```
2590                JSR &FFEE
2591                LDA#24
2592                JSR &FFEE
2593                LDA#39
2594                JSR &FFEE
2595                LDA#2
2596                JSR &FFEE
2597                LDA#tick_tock MOD 256
2598                STA&220
2599                LDA#tick_tock DIV 256
2600                STA &221
2601                JSR tick_tock
2602                LDA#14
2603                LDX#5
2604                JSR &FFF4
2605                RTS
2606  .clock
2607  EQUD &FFFFFF9C
2608  EQUB &FF
2609  .hours EQUB 0
2610  .minutes EQUB 0
2611  .seconds EQUB 0
2612 ]
2613  NEXT
2614  ENDPROC
```

Program 8.1. PROCtime – a background digital clock *(cont.)*.

The initial program call to 'setup' (line 2504) does a number of things. First, it loads the hours, minutes and seconds values previously input into their respective counters (lines 2577 to 2582). A MODE 7 screen is then selected and a text window defined to ensure that the digital clock cannot be scrolled off the screen. Lines 2597 to 2600 reset the EVNTV vector to point to the 'tick_tock' routine at line 2505. The final lines (lines 2602 and 2603) perform an *FX14,5 which balances the previous *FX13,5 (line 30). These two calls disable and enable the interval timer crossing zero event.

The rest of the program's operation is straightforward. Each time the event occurs 'tick_tock' is entered and the interval timer reset to count a further second (lines 2511 to 2514). Note that on entry to the routine all processor registers are preserved. This is very important, otherwise the processor would probably crash when it returned to take up the task it was undertaking before the event occurred.

Lines 2515 to 2532 simply update the seconds, minutes and hours counters as required. The code between lines 2534 to 2546 stores the latest clock value at the top left-hand corner of the screen. The display subroutine (line 2554) called by the program performs a

simple hex to decimal ASCII conversion by continually subtracting 10 from the value to be displayed.

Finally, the processor registers are restored (lines 2547 to 2552) before control is transferred back to the interrupted program.

Program fact sheet

Program 8.1

Procedure title	:	PROCtime
Variables required	:	gethrs, getmins, getsecs, addr
Line numbers	:	2500 to 2614
Zero page requirements	:	none
Registers changed	:	none

Chapter Nine

Error, Pack and Autorun

Error Lister (Program 9.1)

This utility can be of great help at the initial run-time debugging stage of a program. Normally, if an error occurs, one of the Beeb's terse error messages is issued and you are left to list the line referenced often scratching your head wondering just where the problem is. The most infuriating part of debugging is when you make what amounts to a fundamental mistake to which you remain blind, no matter how many times you run and list the erroneous line. I speak from frequent experience!

One way around the error problem is to incorporate an error handling procedure in your program, starting the program off with a line such as:

```
10 ON ERROR GOTO 5000
```

At line 5000, the error message and line can be printed out. The problem still remains that the erroneous line is not listed, nor is the source of the error listed.

Program 9.1 solves both these problems. After being set up and installed, errors occurring at run-time will be treated in the normal manner except that the line containing the error will be listed starting at the point of the error, thus highlighting the mistake. For example, the program line

```
10 PRINT"HELLO" : STUPID ERROR : VDU 7
```

would normally result in the error:

```
Mistake at line 10
```

at run-time. With the new error lister inserted, the response would be

```
STUPID ERROR : VDU 7
Mistake at line 10
```

```
  10 REM *** ERROR LISTER ***
  20 PROCerror (&C00)
  30 *KEY0 CALL &C00|M
  40 *KEY1 CALL &C24|M
  50 END
  60 :
2620 DEF PROCerror (addr)
2621 FOR pass=0 TO 3 STEP3
2622 brkv=?&202+(?&203*256)
2623 P%=addr
2624 [
2625            OPT pass
2626 .SETUP
2627            LDX #0
2628 .next_chr
2629            LDA message,X
2630            JSR &FFE3
2631            INX
2632            CMP #13
2633            BNE next_chr
2634            LDA &202
2635            STA address
2636            LDA &203
2637            STA address+1
2638            LDA #entry MOD 256
2639            STA &202
2640            LDA #entry DIV 256
2641            STA &203
2642            RTS
2643 .restore
2644            LDX #0
2645 .next_chr
2646            LDA message2,X
2647            JSR &FFE3
2648            INX
2649            CMP#13
2650            BNE next_chr
2651            LDA address
2652            STA &202
2653            LDA address+1
2654            STA &203
2655            RTS
2656 .entry
2657            BIT &FF
2658            BMI was_esc
2659            CLC
2660            LDA &1B
2661            ADC &39
```

Program 9.1. PROCerror – lists the program line in which an error occurred.

```
2662             TAX
2663             LDY #0
2664             JSR &FFE7
2665 .next_error
2666             LDA (&19),Y
2667             CMP #13
2668             BEQ was_esc
2669             CMP #32
2670             BCC garbage
2671             CMP #&80
2672             BCS garbage
2673             JSR &FFEE
2674 .garbage
2675             INY
2676             DEX
2677             BNE next_error
2678 .was_esc
2679             JMP brkv
2680 .message
2681             EQUS" Error Lister On!"
2682             EQUB 7
2683             EQUB 13
2684 .message2
2685             EQUS" Error Lister Off!"
2686             EQUB 7
2687             EQUB 13
2688 .address
2689             EQUS"  "
2690 ]
2691 NEXT
2692 ENDPROC
```

Program 9.1. PROCerror – lists the program line in which an error occurred *(cont.)*.

The section of line which created the mistake has been listed in addition to the normal error message.

The assembled program occupies just 141 bytes and is completely self-contained so that it can be tucked out of the way during debugging. As with other programs of this type in the Portfolio, there are two entry points — to switch the lister on (entry at line 2626) and off (entry at line 2643). The 'setup' section of code saves the normal contents of BRKV at &202 and revectors it to point to 'entry' at line 2656.

When the interpreter causes the program to abort via BRKV the new wedge coding is executed. It begins first at line 2657 by testing bit 7 of location &FF. If this bit is set then the abortion was due to the ESCAPE key being pressed and so the normal 'brkv' is jumped to.

Assuming that ESC was not pressed, the length of the current expression being evaluated by the interpreter, and the one that caused the error to occur, is calculated. The bytes at &1B and &39 are summed (lines 2659 to 2662) and the result moved into the X register. Location &1B contains the current offset for the expression evaluation pointer while &39 contains the actual length of the expression.

The address of the current expression is held in the vector at &19 which is known as the expression evaluation base pointer, and each byte is in turn accessed and printed to the screen (line 2666). If a carriage return is encountered, the end of the line has been reached and the program jumps to the normal 'brkv' for the printing of the error message (lines 2667 and 2668). The comparisons of lines 2669 and 2671 ensure that no garbage gets printed to the screen, should the program crash have caused any to have been poked into the program inadvertently.

A compact Pack (Program 9.2)

'Pack' is basically a simple program compacter that, when called, removes all traces of spaces and REM statements from it, leaving behind just the minimal program. There are two advantages in doing this. First, the program becomes smaller, and in the case of some programs much smaller. Second, by virtue of being smaller, they run and execute much faster: even a single space slows a program down a fraction, so a hundred spaces will slow a program down that much more! The saving in memory can make the difference between a program running in a high resolution mode and the dreaded 'Bad Mode' message being reported.

Pack searches through a program in the current text space and looks for spaces and REM statements and the messages that follow them. Of course, the program doesn't wipe the spaces and REMs out; rather, it just shifts the top end of the program down a byte or bytes to write over the offending space or REM.

Program 9.2 begins by placing the current value of PAGE into two zero page vectors (lines 2705 to 2710). These are used to keep position in the current program and point to the same, packed position, in the new program. A special byte is also cleared: this is the 'rem_flag' and is used to indicate if a REM statement is currently being processed.

The heavy work of the program is performed by the subroutine, 'transfer' at lines 2784 to 2789. This moves a byte from its current

```
   10 REM *** SPACE & REM REMOVER ***
   20 PROCpack (&70,&72,&C00)
   30 END
   40 :
 2700 DEF PROCpack (current,new_position
,addr)
 2701 FOR pass=0 TO 3 STEP3
 2702 P%=addr
 2703 [
 2704            OPT pass
 2705            LDA #0
 2706            STA new_position
 2707            STA current
 2708            LDA &18
 2709            STA new_position+1
 2710            STA current+1
 2711 .outer
 2712            LDA #0
 2713            STA rem_flag
 2714            LDY #1
 2715            JSR transfer
 2716            CMP #&FF
 2717            BEQ all_done
 2718            JSR transfer
 2719            JSR transfer
 2720 .inner
 2721            LDA (current),Y
 2722            BIT rem_flag
 2723            BPL flag_clear
 2724            CMP #13
 2725            BNE space
 2726            JSR transfer
 2727            BEQ end_of_line
 2728 .flag_clear
 2729            CMP #ASC" "
 2730            BEQ space
 2731             CMP #&F4
 2732            BNE not_rem
 2733            DEY
 2734            LDA #&FF
 2735            STA rem_flag
 2736            BNE space
 2737 .not_rem
 2738            JSR transfer
 2739            BEQ end_of_line
 2740            CMP #&22
 2741            BEQ inside_quote
 2742            BNE inner
```

Program 9.2. PROCpack – a space and REM remover.

```
2743 .space
2744           INC current
2745           BNE inner
2746           INC current+1
2747           BNE inner
2748 .end_of_line
2749           DEY
2750           TYA
2751           PHA
2752           CPY #3
2753           BEQ clear
2754           LDY #3
2755           STA (new_position),Y
2756           CLC
2757           ADC new_position
2758           STA new_position
2759           BCC clear
2760           INC new_position+1
2761 .clear
2762           PLA
2763           CLC
2764           ADC current
2765           STA current
2766           BCC outer
2767           INC current+1
2768           BNE outer
2769 .inside_quote
2770           JSR transfer
2771           BEQ end_of_line
2772           CMP #&22
2773           BNE inside_quote
2774           BEQ inner
2775 .all_done
2776           LDA new_position
2777           CLC
2778           ADC #2
2779           STA &12
2780           LDA new_position+1
2781           ADC #0
2782           STA &13
2783           RTS
2784 .transfer
2785           LDA (current),Y
2786           STA (new_position),Y
2787           INY
2788           CMP #13
2789           RTS
2790 .rem_flag
```

Program 9.2. PROCpack – a space and REM remover *(cont.)*.

```
2791              EQUS " "
2792 ]
2793 NEXT
2794 ENDPROC
```

Program 9.2. PROCpack - a space and REM remover *(cont.)*.

position in the program undergoing packing to the final version. Post-indexed addressing is used throughout. After the subroutine call, the byte just moved is tested for TOP, by comparing it with &FF (line 2716) in which case the pack is complete. Note that at the start of each line an extra two transfers are required to move the line number down (lines 2718 and 2719).

The space and REM tests are performed in lines 2729 and 2731 respectively and the corresponding branch made accordingly. If a space is detected, the 'current' vector is incremented, no change is made to the 'new_position' vector and the space is not transferred. Thus, effectively the space gets lost as illustrated in Figure 9.1.

The REM test looks for the token for REM which is &F4. If the token is found &FF is placed in the 'rem_flag' to indicate this - so that the program knows it is within a REM statement and is, in fact, 'deleting' items from the line rather than transferring them. A branch

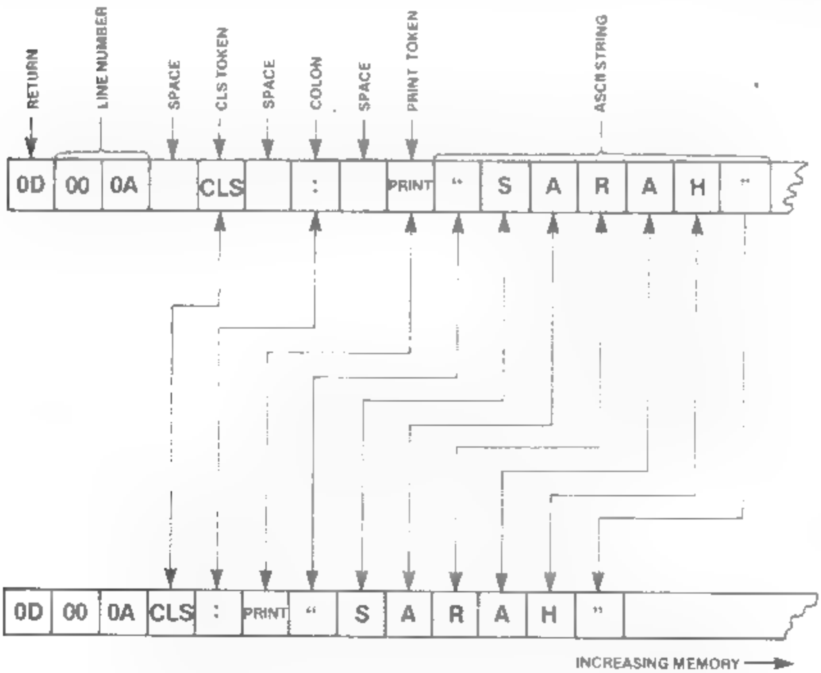


Fig. 9.1. Overwriting bytes to compact a program.

to 'space' (line 2736) increments the 'current' vector before a branch to 'inner' is forced.

The relevant instruction here is in line 2722, where the 'rem_flag' is tested with BIT. If the flag is clear, the following branch is executed, otherwise the 'current' vector is incremented via 'space'. This entire process continues until the end of line return character is encountered (line 2724). The 'end_of_line' routine (line 2748) rapidly transfers the three-byte line header, as comparing this would be an utter waste of processor time.

Occasionally, spaces are required by programs. The most obvious occasion is within ASCII strings where they are used for formatting text. The 'inside_quote' coding ensures that any spaces occurring within the boundary of quotes are not removed. This section is entered via line 2741.

Autorun (Program 9.3)

This program is interesting in that once run you cannot stop it from automatically running the program at PAGE. No matter what combination of keys you try, be it ESCAPE, BREAK or even CTRL-BREAK the program runs! In fact, the only way to be rid of it is to turn off the power to the Beeb, so this makes it an easy way to protect your own programs from the hackers.

```
>LIST
    0 REM!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!
   10 PROCautorun
   20 END
   30 :
 2800 DEF PROCautorun
 2801 *FX247,76
 2802 *FX248,6
 2803 A%=249
 2804 Y%=0
 2805 X%=PAGE DIV 256
 2806 CALL &FFF4
 2807 P%=PAGE+6
 2808 [
 2809            LDA #138
 2810            LDX #0
 2811            LDY #ASC("O")
```

Program 9.3. PROCautorun – will automatically run a program no matter what!

```
2812              JSR &FFF4
2813              LDY #ASC("L")
2814              JSR &FFF4
2815              LDY #ASC("D")
2816              JSR &FFF4
2817              LDY #14
2818              DEY
2819              JSR &FFF4
2820              LDY #ASC("R")
2821              JSR &FFF4
2822              LDY #ASC("U")
2823              JSR &FFF4
2824              LDY #ASC("N")
2825              JSR &FFF4
2826              LDY #14
2827              DEY
2828              JSR &FFF4
2829              RTS
2830 ]
2831 ENDPROC
```

Program 9.3. PROCautorun – will automatically run a program no matter what! *(cont.)*

The assembler is quite straightforward: an *FX 138 call is used to place the string "OLD<RETURN> RUN<RETURN>" into the keyboard buffer. It is not possible, however, to use this call to poke a return character, ASCII 13, into the buffer. To get round this, the Y register is loaded with 14 and then decremented (lines 2817 and 2826).

The machine code is assembled in a rather strange place - in fact, it overwrites the 50 exclamation marks after the REM statement in line 0. As you can see, P% is set to PAGE+6 in line 2807. If you run the program then list it you will see that the !s are replaced by gobbledygook: this is just the interpreter trying to de-tokenise the machine code. These will have no effect when the program is run as they are away from the program, hiding behind the REM statement.

The magic part of the program comes in lines 2801 to 2806. Here the BREAK intercept codes controlled by *FX247, *FX248 and *FX249 are rewritten to point the BRK handler to the code now stored at PAGE+6, so whenever any sort of BREAK is performed the interpreter comes here and OLDs and re-RUNs the program.

Once the program has been run, only line 0 need remain: the others can be deleted as required.

Program fact sheets

Program 9.1

Procedure title	: PROCerror
Variables required	: addr
Line numbers	: 2620 to 2692
Length	: 141 bytes
Zero page requirements	: none
Registers changed	: A, X, Y

Program 9.2

Procedure title	: PROCpack
Variables required	: addr
Line numbers	: 2700 to 2794
Length	: 149 bytes
Zero page requirements	: 4 bytes
Registers changed	: A, X, Y

Program 9.3

Procedure title	: PROCautorun
Variables required	: addr
Line numbers	: 2800 to 2831
Length	: 53 bytes (inside program)
Zero page requirements	: none
Registers changed	: A, X, Y

Chapter Ten
The Necessary Evil

Machine code programs of any length will often be required to manipulate numbers. Addition, subtraction, multiplication, division are all necessary evils in the computer world of data and figure manipulation. This chapter presents routines that should be versatile enough to cover most applications though often, by definition, they will be wasteful of memory and processor time. For example, rather than providing a procedure that will handle the multiplication of two eight-bit numbers a multi-byte multiplication procedure is provided. There is no reason, however, why you - the programmer - could not add a single-byte procedure to this Portfolio.

The programs provided in this chapter are as follows:

Program 10.1 : Multi-byte addition.
Program 10.2 : Multi-byte subtraction.
Program 10.3 : Multi-byte multiplication.
Program 10.4 : Multi-byte division.
Program 10.5 : Single-byte square root.
Program 10.6 : Double-byte square root.
Program 10.7 : Double-byte ASL.
Program 10.8 : Double-byte LSR.
Program 10.9 : Double-byte ROR.
Program 10.10: Double-byte ROL.
Program 10.11: Multi-byte ASL.

Multi-byte Addition (Program 10.1)

Program 10.1 uses the post-indexed indirect address capabilities of the Beeb's 6502 to sum two sets of bytes stored anywhere in the Beeb's memory map, depositing the result over the first number. The start address of the two number sets is stored in the vectors 'first' and

```
  10 REM *** MULTI-BYTE ADDITION ***
  20 PROCmulti_add(&70,&71,&73,&C00)
  30 @%=0
  40 ?&70=4
  50 !&71=&4000
  60 !&73=&4100
  70 !&4000=123456
  80 !&4100=123456
  90 PRINT'''"123456+123456=";
 100 CALL mbadd
 110 PRINT!&4000
 120 END
 130 :
5000 DEF PROCmulti_add(count,first,seco
nd,addr)
5001 FOR PASS=0 TO 3 STEP 3
5002 P%=addr
5003 [
5004           OPT PASS
5005 .mbadd
5006           LDX count
5007           LDY #0
5008           CLC
5009 .next_byte
5010           LDA (first),Y
5011           ADC (second),Y
5012           STA (first),Y
5013           INY
5014           DEX
5015           BNE next_byte
5016           RTS
5017 ]
5018 NEXT
5019 ENDPROC
```

Program 10.1. PROCmulti_add – adds two multi-byte numbers together.

'second'. These variables must therefore be assigned addresses in zero page. A further variable, count, is required and this should contain the number of bytes to be summed which is transferred into the X register to act as the bytes to add counter.

The program is simply an addition routine controlled by a loop counter. After seeding the index registers (lines 5005 to 5008) the carry flag is initially cleared. The 'first' byte is sourced and added to the 'second' byte with the result being stored at 'first' (lines 5009 to 5012). The index registers are adjusted and the loop reiterated until X becomes zero (lines 5013 to 5015).

Since the index registers are only capable of holding a maximum

value of 255 the number of bytes to add together is limited to this value.

Multi-byte Subtraction (Program 10.2)

Program 10.2 operates identically to the last one. The only difference is that the SBC and the SEC instructions are substituted for their addition counterparts. It is important to remember that the 'second' value is subtracted from the 'first'.

```
  10 REM *** MULTI-BYTE SUBTRACTION ***
  20 PROCmulti_sub(&70,&71,&73,&C00)
  30 @%=0
  40 ?&70=4
  50 !&71=&4000
  60 !&73=&4100
  70 !&4000=123456
  80 !&4100=3456
  90 PRINT'''"123456-3456=";
 100 CALL mbsub
 110 PRINT!&4000
 120 END
 130 :
5030 DEF PROCmulti_sub(count,first,seco
nd,addr)
5031 FOR pass=0 TO 3 STEP 3
5032 P%=addr
5033 [
5034           OPT pass
5035 .mbsub
5036           LDX count
5037           LDY #0
5038           SEC
5039 .next_byte
5040           LDA (first),Y
5041           SBC (second),Y
5042           STA (first),Y
5043           INY
5044           DEX
5045           BNE next_byte
5046           RTS
5047 ]
5048 NEXT
5049 ENDPROC
```

Program 10.2. PROCmulti_sub – subtracts one multi-byte number from another.

Multi-byte Multiplication (Program 10.3)

Program 10.3 takes two multi-byte numbers (unsigned) stored low byte first, multiplies the 'first' by the 'second' and stores the result over the 'first'. In addition to requiring two vectored addresses, a 256-byte work buffer is required by the program. The TOTAL number of bytes to be multiplied together is expected in 'totlen' while the variable 'count' is used as a general loop counter by the program.

The multiplication technique employed is a standard add-and-shift one. If the current bit being tested in the multiplier is a one, the multiplicand is added to the partial product, which is then rotated by one bit. If, on the other hand, the multiplier bit is 0 only the rotate is performed.

Because of the way 'mb_mult' is implemented, only the least significant bytes of the product are returned, i.e. the total number of bytes in the multiplier and multiplicand. The most significant bytes are always available in 'buffer' if required. Therefore, the user should check the 'buffer' for any overflow if it is suspected.

```
   10 REM *** MULTI BYTE MULTIPLICATION
 ***
   20 PROCmulti_mult (&70,&72,&74,&75,&4
000,&4200)
   30 !&70=&3000
   40 !&72=&3100
   50 ?&74=4
   60 !&3000=1234
   70 !&3100=1234
   80 CALL mb_mult
   90 PRINT"Result of multiplication :";
  100 PRINT!&3000
  110 END
  120 :
 5050 DEF PROCmulti_mult(first,second,to
tlen,count,buffer,addr)
 5051 FOR pass=0 TO 3 STEP 3
 5052 P%=addr
 5053 [
 5054           OPT pass
 5055 .mb_mult
 5056           LDA second
 5057           SEC
 5058           SBC #1
 5059           STA second
 5060           LDA second+1
```

Program 10.3. PROCmulti_mult – multiplies two multi-byte numbers.

```
5061            SBC #0
5062            STA second+1
5063            LDA first
5064            SEC
5065            SBC #1
5066            STA first
5067            LDA first+1
5068            SBC #0
5069            STA first+1
5070            LDA totlen
5071            BEQ finished
5072            STA count
5073            LDA #0
5074            ASL count
5075            ROL A
5076            ASL count
5077            ROL A
5078            ASL count
5079            ROL A
5080            STA count+1
5081            INC count
5082            BNE over
5083            INC count+1
5084 .over
5085            LDX totlen
5086            LDA #0
5087 .save_loop
5088            STA buffer-1,X
5089            DEX
5090            BNE save_loop
5091            CLC
5092 .loop
5093            LDX totlen
5094 .rotate_loop
5095            ROR buffer-1,X
5096            DEX
5097            BNE rotate_loop
5098            LDY totlen
5099 .rotate_save
5100            LDA (first),Y
5101            ROR A
5102            STA (first),Y
5103            DEY
5104            BNE rotate_save
5105            BCC no_add
5106            LDY #1
5107            LDX totlen
5108            CLC
```

Program 10.3. PROCmulti_mult – multiplies two multi-byte numbers *(cont.)*.

```
5109 .add_loop
5110             LDA (second),Y
5111             ADC buffer-1,Y
5112             STA buffer-1,Y
5113             INY
5114             DEX
5115             BNE add_loop
5116 .no_add
5117             DEC count
5118             BNE loop
5119             LDX count+1
5120             BEQ finished
5121             DEX
5122             STX count+1
5123             JMP loop
5124 .finished
5125             RTS
5126 ]
5127 NEXT
5128 ENDPROC
```

Program 10.3. PROCmulti_mult – multiplies two multi-byte numbers *(cont.)*.

The program operates as follows:

Lines 5056 to 5062: Subtract 1 from address of 'second'.
Lines 5063 to 5069: Subtract 1 from address of 'first'.
Lines 5070 to 5071: If total length is zero then end.
Lines 5072: Set number of bytes to count.
Lines 5073 to 5079: Multiply count by eight.
Lines 5080 to 5083: Add one to value of count.
Lines 5084 to 5091: Save high product in buffer.
Lines 5092 to 5098: Shift carry bit into buffer and bit 0 of high product into the carry flag.
Lines 5099 to 5104: Rotate carry into most significant bit of 'first' and shift next bit of multiplier into the carry flag.
Line 5105: Carry clear so no addition required.
Lines 5106 to 5115: Carry flag is set so add 'second' and high product together.
Lines 5116 to 5123: Decrement bit count and exit if zero, else repeat for the next bit.

The lines of BASIC show how the routine needs to be set up before calling it. In a larger assembler program these introductory peeks and pokes would be performed using assembler and the multiplication routine called as a subroutine from the main program. Lines 30 and 40 place the two addresses of data into the zero page vectors, while

lines 60 and 70 place the values to be multiplied (both 1234) into these data buffers. Previously, in line 50, the total number of bytes to be combined, four (1234 can be held in two bytes), is poked into location &74 which corresponds to the variable 'totlen' in the procedure. After calling the subroutine (line 80) the final result is displayed. Check it on a calculator if you wish!

Multi-byte Division (Program 10.4)

Program 10.4 will divide two unsigned multi-byte number using a standard shift and subtract procedure whereby a 1 is placed in the quotient each time a subtraction is possible, and a 0 if not. The dividend is located at 'first' and the divisor at 'second'; during the division the quotient overwrites the dividend. Any remainder from the division is placed at the address given by 'hidiv_pointer'.

```
   10 REM *** MULTI BYTE DIVISION ***
   20 PROCmult_div(&70,&72,&74,&75,&77,&
79,&3000,&3100,&4000)
   30 !&70=&3400
   40 !&72=&3500
   50 ?&74=3
   60 !&3400=10000
   70 !&3500=2
   80 CALL &4000
   90 PRINT "Result is :";
  100 PRINT!&3400
  110 PRINT"Remainder :";
  120 PRINT
  130 END
  140 :
 5150 DEF PROCmult_div(first,second,totl
en,count,hidiv_pointer,pointer,buffer1,b
uffer2,addr)
 5151 FOR pass=0 TO 3 STEP 3
 5152 P%=addr
 5153 [
 5154           OPT pass
 5155 .multi_div
 5156           LDA totlen
 5157           BNE begin
 5158           JMP okay_out
 5159 .begin
 5160           STA count
 5161           LDA #0
```

Program 10.4. PROCmulti_div – divides one multi-byte number by another.

```
5162            ASL count
5163            ROL A
5164            ASL count
5165            ROL A
5166            ASL count
5167            ROL A
5168            STA count+1
5169            INC count
5170            BNE over
5171            INC count+1
5172 .over
5173            LDX totlen
5174            LDA #0
5175 .clear
5176            STA buffer1-1,X
5177            STA buffer2-1,X
5178            DEX
5179            BNE clear
5180            LDA #buffer1 MOD 256
5181            STA hidiv_pointer
5182            LDA #buffer1 DIV 256
5183            STA hidiv_pointer+1
5184            LDA #buffer2 MOD 256
5185            STA pointer
5186            LDA #buffer2 DIV 256
5187            STA pointer+1
5188            LDX totlen
5189            LDY #0
5190            TYA
5191 .check
5192            ORA (second),Y
5193            INY
5194            DEX
5195            BNE check
5196            CMP #0
5197            BNE divide
5198            JMP error
5199 .divide
5200            CLC
5201 .set_loop
5202            LDX totlen
5203            LDY #0
5204 .loop
5205            LDA (first),Y
5206            ROL A
5207            STA (first),Y
5208            INY
5209            DEX
```

Program 10.4. PROCmulti_div – divides one multi-byte number by another *(cont.)*.

```
5210              BNE loop
5211 .dec_count
5212              DEC count
5213              BNE set_shift
5214              LDX count+1
5215              BEQ okay_out
5216              DEX
5217              STX count+1
5218 .set_shift
5219              LDX totlen
5220              LDY #0
5221 .shift_loop
5222              LDA (hidiv_pointer),Y
5223              ROL A
5224              STA (hidiv_pointer),Y
5225              INY
5226              DEX
5227              BNE shift_loop
5228              LDY #0
5229              LDX totlen
5230              SEC
5231 .subtract
5232              LDA (hidiv_pointer),Y
5233              SBC (second),Y
5234              STA (pointer),Y
5235              INY
5236              DEX
5237              BNE subtract
5238              BCC set_loop
5239              LDY hidiv_pointer
5240              LDX hidiv_pointer+1
5241              LDA pointer
5242              STA hidiv_pointer
5243              LDA pointer+1
5244              STA hidiv_pointer+1
5245              STY pointer
5246              STX pointer+1
5247              JMP set_loopOFF
5248 .okay_out
5249              CLC
5250              BCC finished
5251 .error
5252              SEC
5253 .finished
5254              RTS
5255 ]
5256 NEXT
5257 ENDPROC
```

Program 10.4. PROCmulti_div – divides one multi-byte number by another *(cont.)*.

The total number of bytes to be referenced in the division is placed in 'totlen' prior to the call. On exit from the routine, the carry flag bit is set if an error occurred during the division – otherwise it returns clear. The program operates as follows:

Lines 5156 to 5158: Get 'totlen' if zero then perform a no error finish.
Lines 5160 to 5166: Set count and then multiply by 8 to obtain total number of bits to do.
Lines 5167 to 5171: Add one to bit counter.
Lines 5173 to 5179: Initialise the high dividend result buffer to zero.
Lines 5180 to 5187: Point vectors to buffers.
Lines 5188 to 5198: Check that the divisor, held in 'second' is not zero!
Lines 5199 to 5200: Clear carry flag on entry into 'divide'.
Lines 5201 to 5210: Move the carry flag bit into the low dividend, 'first', to use as the next quotient bit. Then move the most significant bit of the low dividend into the carry flag bit.
Lines 5211 to 5217: Decrement 'count' by one and branch to 'okay_out' if all bits are done.
Lines 5218 to 5227: Transfer the carry flag bit into the least significant bit of the high dividend.
Lines 5228 to 5237: Subtract 'second' from high dividend and save result at 'pointer'.
Lines 5238 to 5246: If the carry flag bit is set then the trial subtraction worked! Therefore, set the quotient bit and switch pointers to replace remainder and dividend. If the carry flag is clear, the trial subtraction failed; therefore skip swap over and branch direct as next quotient bit is zero.
Line 5247: Do next bit.
Lines 5248 to 5250: Finished with no errors detected.
Lines 5251 to 5254: Finished with an error present.

Once again, the first few programs lines show how the procedure can be set up, using BASIC. The procedure is assembled passing workspace, vectors and buffer locations as parameters (line 20). The two vectors at 'first' and 'second' are poked with buffer addresses (lines 30 and 40), which are subsequently seeded with the dividend and divisor (lines 60 and 70). The dividend is 10000 and the divisor 2, which require a total of three bytes' storage, as indicated in line 50 which pokes the byte count into 'totlen'.

After calling the routine the result is extracted from the buffer at &3400 and the remainder from the buffer at &3000.

The odd square root

Finding the square root of a number in machine code might at first sight seem rather difficult. However, there is a quite straightforward solution. The method is simply this: 'the square root of an integer number is equal to the total number of successively higher odd integer numbers that can be subtracted from it'. Consider the number 36: first we subtract one from it, then three, then five and so on until we have no remainder. The total number of odd numbers subtracted is its square root! Thus,

36−1=35 : partial root = 1
35−3=32 : partial root = 2
32−5=27 : partial root = 3
27−7=20 : partial root = 4
20−9=11 : partial root = 5
11−11=0 : final square root = 6

If the final partial root does not yield a result of 0 then a remainder is available which can be 'floated' to provide the decimal portion of the root.

Program 10.5 provides a suitable assembler-based procedure to calculate the square root of any single byte number located at 'byte'. The Y register is used to keep a count of the partial root which is incremented each time round the 'loop'. The location at 'byte+1' is used to hold the odd number to be subtracted. The final root is deposited in 'byte' and any remainder at 'byte+1'.

```
  10 REM ***SINGLE BYTE SQUARE ROOT***
  20 PROConebyte_square(&70,&C00)
  30 ?&70=170
  40 CALL square
  50 PRINT"Square root =";?&70
  60 PRINT"remainder   =";?&71
  70 END
  80 :
5270 DEF PROConebyte_square(byte,addr)
5271 FOR pass=0 TO 3 STEP 3
5272 P%=addr
5273 [
5274            OPT pass
5275 .square
5276            LDY #0
5277            LDA #1
```

Program 10.5. PROConebyte_square – calculates the square root of a single-byte number.

```
5278            STA byte+1
5279            LDA byte
5280 .loop
5281            CMP byte+1
5282            BCC finished
5283            SBC byte+1
5284            INY
5285            INC byte+1
5286            INC byte+1
5287            JMP loop
5288 .finished
5289            STY byte
5290            STA byte+1
5291
5292 ]
5293 NEXT
5294 ENDPROC
```

Program 10.5. PROConebyte_square – calculates the square root of a single-byte number *(cont.)*.

Program 10.5 is simple but effective. On entry to 'square' (line 5275) the Y register is initialised ready to take the partial root count; the accumulator is loaded with the first odd number to be subtracted which is then written to the location 'byte+1' (lines 5276 to 5279). The subtract and count loop is embodied in lines 5280 to 5287. Line 5281 begins by comparing the contents from byte (the current remainder) with the next odd number, a clear carry flag denotes that the remainder is less than the next odd number and the program branches to 'finish'. A set carry and line 5283 subtracts the current odd number from the current remainder (line 5283) and the Y register is incremented. Before the loop is redone the two is added to the contents of 'byte+1' to move onto the next odd number (lines 5285 and 5286). Note that the program passes the immediate value through to the procedure for splitting into two bytes and storing in 'block' before the shift is performed. If the value is already held in 'block' then 'do-asl' can be called directly.

Program 10.6 is a double-byte version, Program 10.5 finding the square root of an unsigned 16-bit integer value. The two locations at 'byte' hold the integer value while 'temp' counts the double-byte odd number. The program operates virtually the same as its predecessor; but because a two-byte value is involved a subtraction rather than a compare must be performed initially. To ensure that the final subtraction will not erode any remainder, its possible low order byte is preserved in the X register.

Looking further down the program listing (line 5322) it seems at

```
   10 REM *** TWO BYTE SQUARE ROOT ***
   20 PROCtwobyte_square(&70,&72,&C00)
   30 !&70=1234
   40 CALL two_square
   50 PRINT"Result      =:";?&70
   60 PRINT"Remainder   =:";?&71
   70 END
   80 :
 5300 DEF PROCtwobyte_square(byte,temp,a
ddr)
 5301 FOR pass=0 TO 3 STEP 3
 5302 P%=addr
 5303 [
 5304           OPT pass
 5305 .two_square
 5306           LDY #1
 5307           STY temp
 5308           DEY
 5309           STY temp+1
 5310 .loop
 5311           SEC
 5312           LDA byte
 5313           TAX
 5314           SBC temp
 5315           STA byte
 5316           LDA byte+1
 5317           SBC temp+1
 5318           STA byte+1
 5319           BCC finished
 5320           INY
 5321           LDA temp
 5322           ADC #1
 5323           STA temp
 5324           BCC loop
 5325           INC temp+1
 5326 .finished
 5327           STY byte
 5328           STX byte+1
 5329           RTS
 5330 ]
 5331 NEXT
 5332 ENDPROC
```

Program 10.6. PROCtwobyte_square – calculates the square root of a 16-bit value.

first sight that the odd number counter is only being incremented by one. However, two is actually being added as the carry flag will be set at this point, if it is clear where the branch to 'finish' at line 5319 would have been performed.

By the left!

The final five programs in this chapter deal with double-byte shifts and rotates. It may seem at first that these would be straightforward enough, but this is certainly not the case with the ASL and LSR combinations, as both of these introduce a 0 into bit 0 and bit 7 of the byte they are acting on respectively. Thus, a two-byte ASL will not yield the correct result if the sequence

    ASL byte
    ASL byte+1

is used.

To perform an overall ASL on two bytes, the initial ASL must be followed by a ROL. Program 10.7 illustrates the technique while Figure 10.1 shows what is happening. The ASL of line 5359 moves bit 7 of 'block+1' (the low byte in true 6502 back-to-frontness!) into the carry inserting a 0 into bit 0. Line 5360 then performs a ROL which moves bit 7 in the carry into bit 0 of 'block', shuffling the internal bits up one bit. The last bit, bit 7, falls out into the carry. The two-byte value has also been multiplied by two!

```
   10 REM*** DOUBLE BYTE ASL ***
   20 PROCtwo_byte_asl(1,&70,&C00)
   30 CALLset_asl
   40 FOR loop=1 TO 15
   50 PRINT?&70*256+?&71
   60 CALLdo_asl
   70 NEXT loop
   80 END
   90 :
 5350 DEF PROCtwo_byte_asl(num,block,add
r)
 5351 P%=addr
 5352 [
 5353 .set_asl
 5354              LDA #num DIV 256
 5355              STA block
 5356              LDA #num MOD 256
 5357              STA block+1
 5358 .do_asl
 5359              ASL block+1
 5360              ROL block
 5361              RTS
 5362 ]
 5363 ENDPROC
```

Program 10.7. PROCtwo_byte_asl – arithmetical shift left on a 16-bit value.

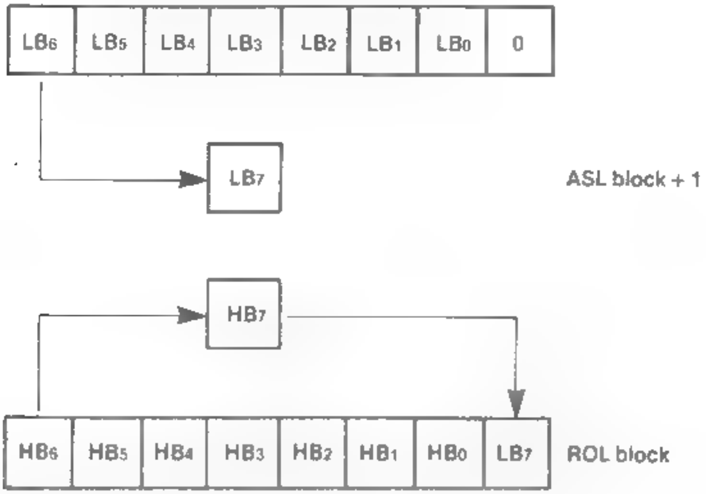


Fig. 10.1. Implementing a 16-bit shift register using an ASL/ROL combination

Program 10.8 works in the opposite direction performing an overall LSR using an LSR and ROR in conjunction. As the shift works in the opposite direction the bytes are referenced in the

```
  10 REM*** DOUBLE BYTE LSR ***
  20 PROCtwo_byte_lsr(65535,&70,&C00)
  30 CALLset_lsr
  40 FOR loop=1 TO 15
  50 PRINT?&70*256+?&71
  60 CALLdo_lsr
  70 NEXT loop
  80 END
  90 :
5370 DEF PROCtwo_byte_lsr(num,block,add
r)
5371 P%=addr
5372 [
5373 .set_lsr
5374                LDA #num DIV 256
5375                STA block
5376                LDA #num MOD 256
5377                STA block+1
5378 .do_lsr
5379                LSR block
5380                ROR block+1
5381                RTS
5382 ]
5383 ENDPROC
```

Program 10.8. PROCtwo_byte_lsr - logical shift right on a 16-bit value.

opposite order to an ASL. The shift is performed on the low byte in 'block' and the rotate on the high byte in 'block+1'. The total effect is to halve the two-byte number.

Programs 10.9 and 10.10 perform double-byte RORs and ROLs respectively. The only difference to note here is the order in which the bytes in 'block' are rotated. In RORing a two-byte number, the low byte is rotated first. With a ROL it is the high byte that is manipulated first.

```
   10 REM*** DOUBLE BYTE ROR ***
   20 PROCtwo_byte_ror(32768,&70,&C00)
   30 CALLset_ror
   40 FOR loop=1 TO 15
   50 PRINT?&70*256+?&71
   60 CALLdo_ror
   70 NEXT loop
   80 END
   90 :
 5390 DEF PROCtwo_byte_ror(num,block,add
r)
 5391 P%=addr
 5392 [
 5393 .set_ror
 5394                LDA #num DIV 256
 5395                STA block
 5396                LDA #num MOD 256
 5397                STA block+1
 5398 .do_ror
 5399                ROR block
 5400                ROR block+1
 5401                RTS
 5402 ]
 5403 ENDPROC
```

Program 10.9. PROCtwo_byte_ror – a double-byte rotate right.

```
   10 REM*** DOUBLE BYTE ROL ***
   20 PROCtwo_byte_rol(1,&70,&C00)
   30 CALLset_rol
   40 FOR loop=1 TO 15
   50 PRINT?&70*256+?&71
   60 CALLdo_rol
   70 NEXT loop
   80 END
   90 :
 5410 DEF PROCtwo_byte_rol(num,block,add
r)
 5411 P%=addr
```

Program 10.10. PROCtwo_byte_rol – a double-byte rotate left.

```
5412 [
5413 .set_rol
5414              LDA #num DIV 256
5415              STA block
5416              LDA #num MOD 256
5417              STA block+1
5418 .do_rol
5419              ROL block+1
5420              ROL block
5421              RTS
5422 ]
5423 ENDPROC
```

Program 10.10. PROCtwo_byte_rol - a double-byte rotate left *(cont.)*.

Finally, Program 10.11 shows how a multi-byte shift, left in this instance, can be implemented on an unsigned value between 2 and 255 bytes in length. The start of the bytes to be shifted are located in 'start' while the number of them is found in 'bytes'. The program commences by placing the 'bytes' count into the Y register and

```
  10 REM *** MULTI LEFT SHIFT     ***
  20 REM *** GIVES 3D CHARACTERS ***
  30 PROCmulti_left (&6000,64,&C00)
  40 MODE 6
  50 PRINT" HELLO THERE!!"
  60 CALL&C00
  70 CALL&C00
  80 END
  90 :
5430 DEF PROCmulti_left (start,bytes,ad
dr)
5431 FOR PASS=0 TO 3 STEP3
5432 P%=addr
5433 [         OPT PASS
5434           LDY bytes
5435           ASL start
5436           LDX #1
5437           DEY
5438 .next
5439           ROL start,X
5440           INX
5441           DEY
5442           BNE next
5443           RTS
5444 ]
5445 NEXT
5446 ENDPROC
```

Program 10.11. PROCmulti_left – performs an arithmetic shift left on a multi-byte number.

performing the initial ASL on 'start' (lines 5434 to 5436). The X register is loaded with one and after decrementing the Y register the 'next' loop is entered (lines 5436 to 5438). From here on, indexed addressing is used to facilitate the ROL on the remaining bytes.

The first handful of lines in the program point out the sort of interesting, and perhaps useful (!), applications the program can be used for. The test of line 50 is printed onto the MODE 6 screen before the memory used to hold the test is shifted left twice (lines 60 and 70). The net effect is to provide 3D text!

Program fact sheets

Program 10.1

Procedure title	:	PROCmulti_add
Variables required	:	count, first, second, addr
Line numbers	:	5000 to 5019
Length	:	16 bytes
Zero page requirements	:	five bytes
Registers changed	:	A, X, Y

Program 10.2

Procedure title	:	PROCmulti_sub
Variables required	:	count, first, second, addr
Line numbers	:	5030 to 5049
Length	:	16 bytes
Zero page requirements	:	5 bytes
Registers changed	:	A, X, Y

Program 10.3

Procedure title	:	PROCmulti_mult
Variables required	:	first, second, totlen, count buffer, addr
Line numbers	:	5050 to 5128
Length	:	114 bytes
Zero page requirements	:	6 bytes
Registers changed	:	A, X, Y

Program 10.4

Procedure title	:	PROCmulti_div
Variables required	:	first, second, totlen, count,

		hidiv_pointer, pointer, buffer1, buffer2, addr
Line numbers	:	5150 to 5257
Length	:	154 bytes
Zero page requirements	:	11 bytes
Registers changed	:	A, X, Y

Program 10.5

Procedure title	:	PROConebyte_square
Variables required	:	byte, addr
Line numbers	:	5270 to 5294
Length	:	27 bytes
Zero page requirements	:	2 bytes
Registers changed	:	A, X, Y

Program 10.6

Procedure title	:	PROCtwobyte_square
Variables required	:	byte, temp, addr
Line numbers	:	5300 to 5332
Length	:	39 bytes
Zero page requirements	:	4 bytes
Registers changed	:	A, X, Y

Program 10.7

Procedure title	:	PROCtwo_byte_asl
Variables required	:	num, block, addr
Line numbers	:	5350 to 5363
Length	:	13 bytes
Zero page requirements	:	2 bytes
Registers changed	:	A

Program 10.8

Procedure title	:	PROCtwo_byte_lsr
Variables required	:	num, block, addr
Line numbers	:	5370 to 5383
Length	:	13 bytes
Zero page requirements	:	2 bytes
Registers changed	:	A

Program 10.9

Procedure title	:	PROCtwo_byte_ror
Variables required	:	num, block, addr

Line numbers	: 5390 to 5403
Length	: 13 bytes
Zero page requirements	: 2 bytes
Registers changed	: A

Program 10.10

Procedure title	: PROCtwo_byte_rol
Variables required	: num, block, addr
Line numbers	: 5410 to 5423
Length	: 13 bytes
Zero page requirements	: 2 bytes
Registers changed	: A

Program 10.11

Procedure title	: PROCmulti_left
Variables required	: start, bytes, addr
Line numbers	: 5430 to 5446
Length	: 16 bytes
Zero page requirements	: 1 byte
Registers changed	: A, X, Y

Chapter Eleven
Vision On

This chapter is devoted entirely to exploring the graphics capabilities of the Beeb from machine code. Many of the procedures are based on the VDU driver routine OSWRCH and all the graphics commands available from BASIC are implemented here plus a few more! These extras include two new screen modes which give scaled down versions of MODE 2 and MODE 5, plus a routine utilising the *640 table in the BASIC interpreter to convert an X, Y coordinate pair into the corresponding screen address.

I use many of these routines as part of a simple graphics compiler (SGC) which uses simple INPUT commands to call the appropriate PROC to compile the necessary machine code - but on to the routines.

Just mode about you

Program 11.1 performs a mode change in machine code. This is done by sending the VDU value 22 to the driver followed by the mode number which should be passed into the procedure via 'action'. The assembled code is very short - just 11 bytes including the RTS.

```
  10 REM *** DO MODE **
  20 CLS
  30 INPUT"Which MODE ?"M%
  40 PROCmode (M%,&C00)
  50 CALL mode
  60 PRINT"This is MODE ";M%
  70 END
  80 :
6000 DEF PROCmode (action,addr)
6001 P%=addr
6002 [
```

Program 11.1. PROCmode – performs a MODE change.

```
6003 .mode
6004            LDA #22
6005            JSR &FFEE
6006            LDA #action
6007            JSR &FFEE
6008            RTS
6009 ]
6010 ENDPROC
```

Program 11.1. PROCmode – performs a MODE change *(cont.)*.

Program 11.2 provides a new screen mode. As it is made out of the MODE 2 screen I have christened it MODE 2A. This new mode still has all the sixteen colours of a normal MODE 2 available but only requires half the memory, 10K, for displaying them. The screen itself is composed of 25 rows of 20 characters. The program is given in its long-winded form so that I can try to explain its operation better! Obviously, it would be more economical in terms of memory to implement the final version with the VDU codes in a look-up table using an indexing routine to pull them out one by one and send them to OSWRCH.

```
  10 REM *** NEW MODE 2A SCREEN ***
  20 PROCmode2A (&A00)
  30 CALL &A00
  40 END
  50 :
6100 DEF PROCmode2A (addr)
6101 FOR PASS=0 TO 3 STEP3
6102 P%=addr
6103 [          OPT PASS
6104           LDA #22
6105           JSR &FFEE
6106           LDA #2
6107           JSR &FFEE
6108           LDA #23
6109           JSR &FFEE
6110           LDA #0
6111           JSR &FFEE
6112           LDA #6
6113           JSR &FFEE
6114           LDA #25
6115           JSR &FFEE
6116           JSR SIX
6117           LDA #23
6118           JSR &FFEE
6119           LDA #0
```

Program 11.2. PROCmode2A – implements a scaled down version of MODE 2.

```
6120            JSR &FFEE
6121            LDA #7
6122            JSR &FFEE
6123            LDA #30
6124            JSR &FFEE
6125            JSR SIX
6126            LDA #23
6127            JSR &FFEE
6128            LDA #0
6129            JSR &FFEE
6130            LDA #12
6131            JSR &FFEE
6132            LDA #8
6133            JSR &FFEE
6134            JSR SIX
6135            LDA #23
6136            JSR &FFEE
6137            LDA #0
6138            JSR &FFEE
6139            LDA #14
6140            JSR &FFEE
6141            LDA #8
6142            JSR &FFEE
6143            JSR SIX
6144            LDA #5
6145            STA &FE40
6146            LDA #56
6147            STA &302
6148            LDA #24
6149            STA &309
6150            LDA #40
6151            STA &D9
6152            STA &34B
6153            STA &34E
6154            STA &351
6155            STA &354
6156            LDA #&40
6157            STA &7
6158            LDA #0
6159            STA &6
6160            RTS
6161 .SIX
6162            LDA #0
6163            LDX #6
6164 .AGAIN
6165            JSR &FFEE
6166            DEX
```

Program 11.2. PROCmode2A – implements a scaled down version of MODE 2 *(cont.).*

```
6167              BNE AGAIN
6168              RTS
6169 ]
6170 NEXT
6171 ENDPROC
```

Program 11.2. PROCmode2A – implements a scaled down version of MODE 2 *(cont.)*.

It might be easier to understand exactly what is going on if the assembler is broken down into its BASIC equivalent which, incidentally, will also produce the desired effect.

Lines 6104 to 6107: MODE 2
Lines 6108 to 6116: VDU 23;6,25;0;0;0;
Lines 6117 to 6125: VDU 23;7,30;0;0;0;
Lines 6126 to 6134: VDU 23;12,8;0;0;0;
Lines 6135 to 6143: VDU 23;14,8;0;0;0;
Lines 6144 to 6145: ?&FE40=5
Lines 6146 to 6147: ?&302=56
Lines 6148 to 6149: ?&309=24
Lines 6150 to 6151: ?&D9=40
Lines 6152 to 6155: ?&34B=40
: ?&34E=40
: ?&351=40
: ?&354=40
Lines 6156 to 6159: HIMEM=&4000

The VDU statements (lines 6108 to 6143) reprogram several registers of the 6845 cathode ray tube controller (CRTC) which is responsible for organising the screen memory. The BASIC equivalents show that the first and second parameter bytes are used in programming the CRTC. The first determines the CRTC register and the second the value to be written into it. Taking the four VDU23 statements in turn they perform the following tasks:

(a) Program number of lines
(b) Set position of vertical sync in number of row times
(c) Set top of screen address
(d) Set cursor position

The remaining pokes write to the VDU variables directly which, strictly speaking, is rather naughty! The poke to &FE40 is writing to the system VIA scroll-controlling register, while the subsequent two pokes define the bottom row, in pixels, of the graphics window and the bottom row of the text window. &D9 holds the high byte of the

current address of the top scan line of a character (HIMEM is being set to &4000, thus the &40); &34B high byte of the top cursor location; &34E top+1 address of user memory; &351 the high byte address of the top left-hand corner of the screen; and finally &354 the high byte of the screen memory size.

Because the screen is not an official mode it is organised rather crookedly. For example, the pixel coordinates for the Y axis do not run from 0 to 1023 as one might expect but from 225 to 1023. Also, the screen itself tends to sit in the middle of the TV rather than using it all. To counteract the Y axis distortion, the graphics origin could be reset to 0,225 using VDU 29, thus:

```
VDU 29,0;225;
MOVE 0,0
```

This will reduce the maximum on-screen Y graphics coordinate to 798 but the range 0 to 798 is easier to use than 225 to 1023! Figure 11.1 provides a suitable map of MODE 2A.

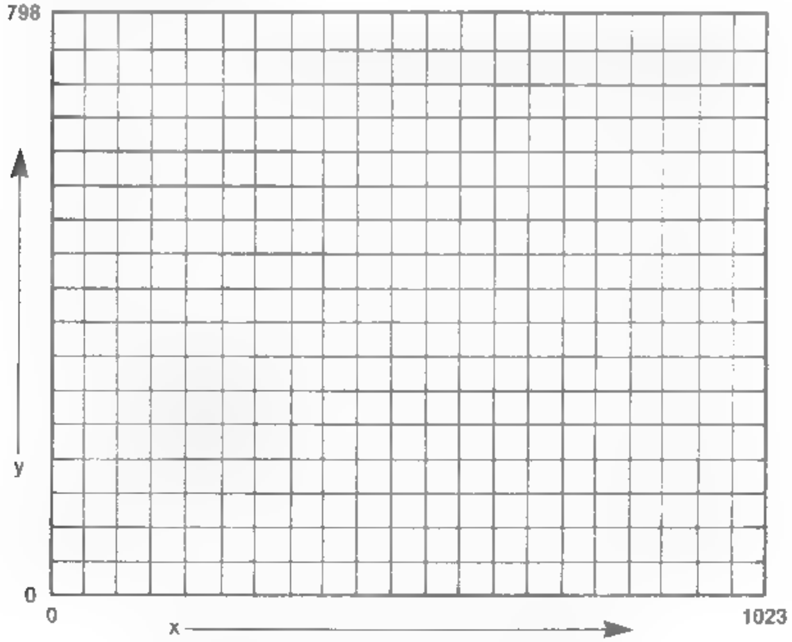


Fig. 11.1. The MODE 2A screen map.

Program 11.3 works along similar lines in that it pokes various VDU variables to set up a new graphics mode screen from MODE 5. However, rather than reprogramming the CRTC, it writes to the Video ULA using an OSBYTE call (lines 6027 to 6030). This writes,

```
  10 REM *** NEW MODE 5A ***
  20 PROCmode5A (&A00)
  30 DRAW1000,100
  40 CALL &A00
  50 MOVE 100,100
  60 DRAW 1000,100
  70 DRAW 1000,1000
  80 DRAW 100,1000
  90 DRAW 100,100
 100 END
 110 :
6020 DEF PROCmode5A (addr)
6021 P%=addr
6022 [
6023           LDA #22
6024           JSR &FFEE
6025           LDA #5
6026           JSR &FFEE
6027           LDA #154
6028           LDX #224
6029           JSR &FFF4
6030           LDA #15
6031           STA &360
6032           LDA #1
6033           STA &361
6034           LDA #32
6035           STA &34F
6036           LDA #&55
6037           STA &363
6038           LDA #&AA
6039           STA &362
6040           LDA #9
6041           STA &30A
6042           LDA #20
6043           JSR &FFEE
6044           LDA #&54
6045           STA &07
6046           LDA #0
6047           STA &6
6048           JMP &FFEE
6049 ]
6050 ENDPROC
```

Program 11.3. PROCmode5A – implements a scaled down version of MODE 5.

in fact, to the Video Control Register whose layout is given in Figure 11.2. The byte written is 224 or &E0 in hex, thus causing a large cursor two bytes in width to be displayed.

7	6	5	4	3	2	1	0
CURSOR SIZE BIT	CURSOR WIDTH BITS		6845 CLOCK BIT	CHARACTERS PER LINE BITS		TELETEXT SELECT BIT	FLASHING COLOUR BIT

Fig. 11.2. The Video Control Register.

This mode requires just 10K of RAM but also allows 16 colours like MODE 2 and MODE 2A! The mode allows 16 rows of 10 characters and HIMEM is set to &5400. The program description follows.

Lines 6023 to 6026: Select MODE 5.
Lines 6027 to 6029: Write to video ULA cursor control bits.
Lines 6030 to 6031: All 16 colours available.
Lines 6032 to 6033: Two 4-bit pixels per byte.
Lines 6034 to 6035: 32 bytes used per character.
Lines 6036 to 6039: Set colour details.
Lines 6040 to 6041: 10 characters on each line (0 to 9).
Lines 6042 to 6043: Do VDU 20 and rest default colours.
Lines 6044 to 6048: Set HIMEM = &5400.

Moving on

The three drawing-orientated processes, MOVE, DRAW and PLOT, can be performed using a VDU25 sequence, once again passing bytes through OSWRCH. After issuing the VDU25 sequence, OSWRCH expects five more bytes to be passed through to it. The first of these determines exactly what function is to be performed, while the remaining four bytes provide the double-byte values of first the X and then the Y coordinates, low bytes first.

Program 11.4 lists a suitable MOVE procedure. The MOVE code is 4 (line 6186) while the X, Y coordinates are passed for immediate addressing through the variables 'xpos' and 'ypos'. The demo uses the procedure to move the graphics cursor to the centre of the screen at 640,512 before plotting a point there (lines 20 to 50).

```
10 REM *** DO MACHINE CODE MOVE ***
20 PROCmove(640,512,&A00)
30 MODE 5
40 CALL move
50 DRAW 640,512
60 END
70 :
```

Program 11.4. PROC move – performs MOVE.

```
6180 DEF PROCmove(xpos,ypos,addr)
6181 P%=addr
6182 [
6183 .move
6184            LDA #25
6185            JSR &FFEE
6186            LDA #4
6187            JSR &FFEE
6188            LDA #xpos MOD 256
6189            JSR &FFEE
6190            LDA #xpos DIV 256
6191            JSR &FFEE
6192            LDA #ypos MOD 256
6193            JSR &FFEE
6194            LDA #ypos DIV 256
6195            JSR &FFEE
6196            RTS
6197 ]
6198 ENDPROC
```

Program 11.4. PROCmove – performs MOVE *(cont.)*.

Program 11.5 uses the driver code 6 (line 6206) to execute the machine code equivalent of a DRAW. The positions passed into the procedure are taken to be the coordinates to draw to. The demo program draws a line diagonally across the MODE 4 screen from 0,0 to 1000,1000. Once again, immediate addressing is used in the program to obtain the X, Y coordinates which must therefore be passed into the procedure at assembly time.

```
  10 REM *** DO MACHINE CODE DRAW LINE ***
  20 PROCdraw(1000,1000,&C00)
  30 MODE 4
  40 MOVE 0,0
  50 CALL &C00
  60 END
  70 :
6200 DEF PROCdraw(xcord,ycord,addr)
6201 P%=addr
6202 [
6203 .draw_line
6204              LDA #25
6205              JSR &FFEE
6206              LDA #6
6207              JSR &FFEE
6208              LDA #xcord MOD 256
6209              JSR &FFEE
```

Program 11.5. PROCdraw – performs DRAW.

```
6210              LDA #xcord DIV 256
6211              JSR &FFEE
6212              LDA #ycord MOD 256
6213              JSR &FFEE
6214              LDA #ycord DIV 256
6215              JSR &FFEE
6216              RTS
6217 ]
6218 ENDPROC
```

Program 11.5. PROCdraw – performs DRAW *(cont.)*.

A PLOT is performed using the driver code which is equivalent to the plot function required. Program 11.6 shows how the PLOT code is passed into the procedure through the variable 'code'. The demo uses code 85 to draw and fill a triangle in a MODE 4 screen. As you may now realise, the previous two programs were, in fact, simply using the plot codes for move and draw.

```
  10 REM *** DO MACHINE CODE PLOT ***
  20 PROCplot(85,1000,1000,&C00)
  30 MODE 4
  40 MOVE 0,0
  50 MOVE 1000,0
  60 CALL plot
  70 END
  80 :
6220 DEF PROCplot(code,xcord,ycord,addr
)
6221 P%=addr
6222 [OPT 2
6223 .plot
6224              LDA #25
6225              JSR &FFEE
6226              LDA #code
6227              JSR &FFEE
6228              LDA #xcord MOD 256
6229              JSR &FFEE
6230              LDA #xcord DIV 256
6231              JSR &FFEE
6232              LDA #ycord MOD 256
6233              JSR &FFEE
6234              LDA #ycord DIV 256
6235              JSR &FFEE
6236              RTS
6237 ]
6238 ENDPROC
```

Program 11.6. PROCplot – performs PLOT.

Paint-box

The use of colour is usually desirable for graphics and both COLOUR and GCOL can be readily performed. Program 11.7 can be used to redefine the text colour used by PRINT. It uses the

```
  10 REM *** DO PRINT COLOUR ***
  20 PROCcolour (1,&C00)
  30 MODE 2
  40 CALL colour
  50 END
  60 :
6250 DEF PROCcolour(print_colour,addr)
6251 P%=addr
6252 [
6253 .colour
6254            LDA #17
6255            JSR &FFEE
6256            LDA #print_colour
6257            JSR &FFEE
6258            RTS
6259 ]
6260 ENDPROC
```

Program 11.7 PROCcolour -performs COLOUR.

Number	Colour
0	Black
1	Red
2	Green
3	Yellow
4	Blue
5	Magenta
6	Cyan
7	White
8	Flashing black white
9	Flashing red-cyan
10	Flashing green magenta
11	Flashing yellow-blue
12	Flashing blue-yellow
13	Flashing magenta-green
14	Flashing cyan red
15	Flashing white-black

Fig. 11.3. The physical colours.

VDU17 command with a second byte in the range 0 to 15 being passed to OSWRCH to define the colour. The number associated with each physical colour is detailed in Figure 11.3 and the chosen value should be passed to the procedure in the 'print_colour' variable. The demo sets up printing in red on a MODE 2 screen.

Program 11.8 shows how the background colour can be redefined using VDU17 again. Essentially the program is the same as its predecessor. To stipulate a background colour, however, the most significant bit of the colour byte must be set. In everyday terms, this simply means adding 128 to the colour value. After passing the background colour to the VDU driver (lines 6276 to 6277) the screen must be cleared. This is facilitated simply by printing the equivalent of a VDU12 (lines 6278 to 6279). The demo program initialises a red MODE 2 screen.

```
  10 REM *** DO BACKGROUND COLOUR ***
  20 REM *** SET RED BACKGROUND ***
  30 PROCbackgrnd (129,&C00)
  40 MODE 2
  50 CALL backgrnd
  60 END
  70 :
6270 DEF PROCbackgrnd (back_col,addr)
6271 P%=addr
6272 [
6273 .backgrnd
6274            LDA #17
6275            JSR &FFEE
6276            LDA #back_col
6277            JSR &FFEE
6278            LDA #12
6279            JSR &FFEE
6280            RTS
6281 ]
6282 ENDPROC
```

Program 11.8. PROCbackgrnd – changes the mode background colour.

Performing GCOL is almost as easy, however. The GCOL statement requires two parameters. After issuing VDU18 first, the byte depicting the action required (i.e. AND, OR, EOR) should be passed to OSWRCH followed by the colour. These bytes are shown in Program 11.9 as 'action' and 'colour' and the associated demo program (lines 10 to 70) set up a flashing black and white diagonal line across the MODE 2 screen.

```
  10 REM *** DO MACHINE CODE GCOL ***
  20 REM *** FLASHING B/W LINE ***
  30 PROCgcol (0,8,&C00)
  40 MODE 2
  50 CALL gcol
  60 MOVE 0,0:DRAW 1000,1000
  70 END
  80 :
6285 DEF PROCgcol (action,colour,addr)
6286 P%=addr
6287 [
6288 .gcol
6289            LDA #18
6290            JSR &FFEE
6291            LDA #action
6292            JSR &FFEE
6293            LDA #colour
6294            JSR &FFEE
6295            RTS
6296 ]
6297 ENDPROC
```

Program 11.9. PROCgcol - performs GCOL.

The graphics screen can be cleared from BASIC using the command CLG. In machine code this is simplicity itself and only requires the vdu driver to print the code 16 through OSWRCH. Program 11.10 demonstrates this.

```
  10 REM**CLEAR GRAPHICS SCREEN -CLG**
  20 PROCclg (&C00)
  30 MODE 2
  40 COLOUR129
  50 CLS
  60 PRINT"PRESS A KEY TO CLEAR SCREEN"
  70 A=GET
  80 CALL &C00
  90 END
 100 :
6300  DEF PROCclg (addr)
6301 P%=addr
6302 [
6303 .clear_graphics
6304                LDA #16
6305                JSR &FFEE
6306                RTS
6307 ]
6308 ENDPROC
```

Program 11.10. PROCclg – performs CLG.

Programming the palette is done as in BASIC using VDU 19 in the form:

VDU 19, log, phy, 0,0,0

where 'log' and 'phy' refer to the logical and physical colours respectively. Program 11.11 shows how this is translated into assembler. After the 19 is printed (lines 6314 and 6315) the logical and physical colour codes are passed to OSWRCH (lines 6316 to 6319) followed by the three padding zeros (lines 6320 to 6323) reserved for future expansion, whatever that is! Once again, the values passed into the procedure for 'log' and 'phy' are interpreted as immediate values by the assembler.

The lines 10 to 110 show how the procedure is used in this case to re-set the current screen background logical colour to each physical colour in turn.

```
   10 REM *** DO VDU 19 ***
   20 REM** GO FRU ALL COLOURS **
   30 MODE 2
   40 FOR loop=1 TO 15
   50 PROCchange_palette (0,loop,&C00)
   60 CALL chgpalette
   70 FOR N=0 TO 999:NEXT
   80 NEXT
   90 PROCchange_palette (0,0,&C00)
  100 CALL chgpalette
  110 END
  120 :
 6310 DEF PROCchange_palette (log,phy,ad
dr)
 6311 P%=addr
 6312 [OPT 2
 6313 .chgpalette
 6314            LDA #19
 6315            JSR &FFEE
 6316            LDA #log
 6317            JSR &FFEE
 6318            LDA #phy
 6319            JSR &FFEE
 6320            LDA #0
 6321            JSR &FFEE
 6322            JSR &FFEE
 6323            JSR &FFEE
 6324            RTS
 6325 ]
 6326 ENDPROC
```

Program 11.11. PROCchange_palette – reprograms the palette using OSWORD.

Read it write!

Occasionally it is useful to be able to know the last two sets of coordinates visited by the graphics cursor, so Acorn have implemented an OSWORD call to enable this feat. The call code is 13 and as with all OSWORD calls an address held with the index registers points to a parameter block where in this case OSWORD deposits the required information, Figure 11.4 details the information contained in the block after the call and Program 11.12 the technique. Lines 10 to 140 demonstrate the call by first moving the

XY+0	:	previous X coordinate LSB
XY+1	:	previous X coordinate MSB
XY+2	:	previous Y coordinate LSB
XY+3	:	previous Y coordinate MSB
XY+4	:	current X coordinate LSB
XY+5	:	current X coordinate MSB
XY+6	:	current Y coordinate LSB
XY+7	:	current Y coordinate MSB

Fig. 11.4. OSWORD 13 parameter block for reading last two graphics coordinates.

graphics cursor to a few positions on the MODE 4 screen before calling the procedure and reading its eight-byte result from the parameter block which in this instant is in zero page.

```
  10 REM *** READ LAST 2 GRAPHICS ***
  20 REM *** CURSOR POSITIONS     ***
  30 MODE 4
  40 MOVE 200,200
  50 DRAW 500,500
  60 MOVE 700,700
  70 DRAW 900,900
  80 CLS
  90 PROCgcursor(&70,&C00)
 100 CALL &C00
 110 FOR loop=&70 TO &77
 120 PRINT~loop;"    ";?loop
 130 NEXT loop
 140 END
 150 :
6330 DEF PROCgcursor(block,addr%)
6331 FOR pass=0 TO 3 STEP3
```

Program 11.12. PROCgcursor – uses OSWORD to read the last two graphics coordinates.

```
6332  P%=addr%
6333  [OPT pass
6334              LDA #13
6335              LDX #block MOD 256
6336              LDY #block DIV 256
6337              JSR &FFF1
6338              RTS
6339  ]
6340  NEXT
6341  ENDPROC
```

Program 11.12. PROCgcursor – uses OSWORD to read the last two graphics coordinates *(cont.)*.

The condition of any pixel on the screen can also be read using OSWORD with the accumulator holding 9 – in effect, mimicking BASIC's POINT command (see Program 11.13). Before calling the operating system routine, the obligatory parameter block (detailed in Figure 11.5) must have some relevant details placed into it, namely the X,Y coordinates of the byte to be tested. Each coordinate uses

```
  10 REM READ PIXEL VALUES
  20 PROCpixel(&70,100,100,&C00)
  30 MODE 2
  40 CALL&C00
  50 PRINT~block?4
  60 END
  70 :
6350 DEF PROCpixel(block,X,Y,addr)
6351 FOR pass=0 TO 3 STEP3
6352 P%=addr
6353 [OPT pass
6354              LDA #X MOD 256
6355              STA block
6356              LDA #X DIV 256
6357              STA block+1
6358              LDA #Y MOD 256
6359              STA block+2
6360              LDA #Y DIV 256
6361              STA block+3
6362              LDX #block  MOD 256
6363              LDY #block  DIV 256
6364              LDA #9
6365              JSR &FFF1
6366              RTS
6367 ]
6368 NEXT
6369 ENDPROC
```

Program 11.13. PROCpixel – reads the state of a screen pixel.

XY+0	:	X coordinate LSB
XY+1	:	X coordinate MSB
XY+2	:	Y coordinate LSB
XY+3	:	Y coordinate MSB
XY+4	:	Logical colour of point. &FF if point off screen.

Fig. 11.5. OSWORD 9 parameter block to perform POINT.

two bytes of the parameter block and these are derived in lines 6345 to 6361 of the procedure. The procedure again assumes that the actual coordinates, and not an address containing them, are passed through the variable X and Y. Each byte is then stored in the relevant parameter block location. After seeding the parameter block address into the index registers (lines 6362 to 6364) the OSWORD call is performed leaving the logical colour of the coordinate in the fifth block of the parameter block – or &FF if the point was off of the screen.

The colour palette can itself be read using an OSWORD 11 as shown in Program 11.14. The logical colour to be read should be

```
  10  REM *** READ COLOUR PALETTE ***
  20 MODE 4
  30 VDU19,1,3,0,0,0
  40 PROCreadpalette (&70,&C00,1)
  50 CALL &C00
  60 PRINT"Logical  colour :";?&70
  70 PRINT"Physical colour :";?&71
  80 END
  90 :
6380 DEF PROCreadpalette (block, addr%,
L%)
6381 FOR pass=0 TO 3 STEP 3
6382 P%=addr%
6383 [OPT pass
6384             LDA #L%
6385             STA block
6386             LDA #11
6387             LDX #block MOD 256
6388             LDY #block DIV 256
6389             JSR &FFF1
6390             RTS
6391 ]
6392 NEXT pass
6393 ENDPROC
```

Program 11.14. PROCreadpalette – reads the physical colour associated with a logical colour.

placed into the five-byte parameter block. After the call, the physical colour currently assigned to the logical colour is in the second byte of the parameter block. The remaining three parameter block bytes contain zero – yes, for future expansion! The BASIC demo uses the call to read the physical colour assigned to logical colour 1 on the MODE 4 screen, this having been defined prior to the call in line 30 as 3.

Program 11.15 performs the operation in the reverse direction by writing to the palette using OSWORD 12. The parameter block is identical to that in a read operation except that the physical colour to be written must also be placed into the parameter block. The procedure passes both logical and physical colours to the assembler through the variables L% and PY%. The demo resets the MODE 4 logical colour 0, the background colour, to physical colour yellow, thereby performing an instant change in background colour.

```
   10 REM *** WRITE TO PALETTE ***
   20 MODE 4
   30 PROCwritepalette (&70,0,3,&C00)
   40 CALL &C00
   50 END
   60 :
 6400 DEF PROCwritepalette (block,L%,PY%
,addr%)
 6401 P%=addr%
 6402 [
 6403              LDA # L%
 6404              STA block
 6405              LDA # PY%
 6406              STA block+1
 6407              LDA #0
 6408              STA block+2
 6409              STA block+3
 6410              STA block+4
 6411              LDA #12
 6412              LDX #block MOD 256
 6413              LDY #block DIV 256
 6414              JSR &FFF1
 6415              RTS
 6416 ]
 6417 ENDPROC
```

Program 11.15. PROCwritepalette - performs VDU 19.

Co-ordinating screen addresses

The final routine in this chapter, Program 11.16, utilises the BASIC interpreter's *640 table at &C357 to convert an XY coordinate position on the screen (MODES 0, 1 and 2 only) into an absolute memory address. The table is a 32 byte by 2 byte affair which, unusually, is presented high byte first.

```
  10 REM ** CONVERT X,Y TO ADDRESS **
  20 PROCxyaddr(&80, &72, &71,&900)
  30 REPEAT
  40 INPUT"What is the X axis value - 0
 to 79  "?&71
  50 INPUT''"What is the Y axis value -
 0 to 255 "?&72
  60 CALLCODE
  70 PRINT~?&80+?&81*256
  80 UNTIL0
  90 :
6500 DEFPROCxyaddr(vector, yaxis, xaxis
, addr)
6501 FORI%=0TO2 STEP2
6502 P%=addr
6503 [          OPTI%
6504 .CODE
6505            LDA#0
6506            STA vector
6507            STA  vector+2
6508            LDA#&30
6509            STA  vector+1
6510            LDA yaxis
6511            AND#7
6512            STA yaxis +1
6513            EOR yaxis
6514            LSRA
6515            LSRA
6516            TAY
6517            INY
6518            LDA&C375,Y
6519            CLC
6520            ADC vector
6521            ADC yaxis +1
6522            STA vector
6523            DEY
6524            LDA&C375,Y
6525            ADC  vector+1
```

Program 11.16. PROCxy_addr – converts an X,Y coordinate into a screen address.

```
6526           STA  vector+1
6527           LDA xaxis
6528           LDX#3
6529 .LOOP
6530           ASLA
6531           ROL  vector+2
6532           DEX
6533           BNE LOOP
6534           ADC vector
6535           STA vector
6536           LDA#0
6537           ADC  vector+2
6538           ADC  vector+1
6539           STA  vector+1
6540           LDY#0
6541           LDA#&FF
6542           STA( vector),Y
6543           RTS
6544 ]
6545 NEXT
6546 ENDPROC
```

Program 11.16. PROCxy addr - converts an X,Y coordinate into a screen address *(cont.)*.

The program begins by clearing a few bytes of memory (lines 6505 to 6509) and setting vector to the start screen address. The MOD 8 value of the 'yaxis' is then calculated along with the DIV 8 value (lines 6510 to 6513). The actual value to be calculated is, in fact, Y DIV 8 *640. However, since the table values are two-byte the DIV is restricted to 4 (lines 6514 to 6516). The accumulator is transferred into the Y register to get the index into the table, and is subsequently incremented to get the second, low byte (lines 6516 to 6518).

The low byte is added to give Y axis MOD 8 (lines 6519 to 6522) and after extracting the high byte from the table this is added to give Y axis DIV 8 *640 (lines 6523 to 6527). Finally, the X axis value is multiplied by 8 and any bits falling off are caught in 'vector+3' (lines 6528 to 6533). This is then added to the low byte of the screen address to give the final address (lines 6534 to 6539). By way of demonstration, &F is then poked into screen memory at this point: to see this the program will need to be run in MODE 2 (lines 6540 to 6542).

Program fact sheets

Program 11.1

Procedure title	: PROCmode
Variables required	: action, addr
Line numbers	: 6000 to 6010
Length	: 11 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.2

Procedure title	: PROCmode2A
Variables required	: addr
Line numbers	: 6100 to 6170
Length	: 153 bytes
Zero page requirements	: none
Registers changed	: A, X

Program 11.3

Procedure title	: PROCmode5A
Variables required	: addr
Line numbers	: 6020 to 6049
Length	: 58 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.4

Procedure title	: PROCmove
Variables required	: xpos, ypos, addr
Line numbers	: 6180 to 6198
Length	: 31 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.5

Procedure title	: PROCdraw
Variables required	: xcord, ycord, addr
Line numbers	: 6200 to 6218
Length	: 31 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.6

Procedure title	: PROCplot
Variables required	: code, xcord, ycord, addr
Line numbers	: 6220 to 6238
Length	: 31 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.7

Procedure title	: PROCcolour
Variables required	: print_colour, addr
Line numbers	: 6250 to 6260
Length	: 11 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.8

Procedure title	: PROCbackgrnd
Variables required	: back_col, addr
Line numbers	: 6270 to 6282
Length	: 16 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.9

Procedure title	: PROCgcol
Variables required	: action, colour, addr
Line numbers	: 6285 to 6297
Length	: 16 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.10

Procedure title	: PROCclg
Variables required	: addr
Line numbers	: 6300 to 6308
Length	: 6 bytes
Zero page requirements	: none
Registers changed	: A

Program 11.11

Procedure title	:	PROCchange_palette
Variables required	:	log, phy, addr
Line numbers	:	6310 to 6326
Length	:	27 bytes
Zero page requirements	:	none
Registers changed	:	A

Program 11.12

Procedure title	:	PROCgcursor
Variables required	:	block, addr
Line numbers	:	6330 to 6341
Length	:	10 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 11.13

Procedure title	:	PROCpixel
Variables required	:	block, X, Y, addr
Line numbers	:	6350 to 6369
Length	:	26 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 11.14

Procedure title	:	PROCreadpalette
Variables required	:	block, addr, L%
Line numbers	:	6380 to 6393
Length	:	14 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 11.15

Procedure title	:	PROCwritepalette
Variables required	:	block, L%, PY%, addr
Line numbers	:	6400 to 6417
Length	:	26 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 11.16

Procedure title	: PROCxy_addr
Variables required	: vector, yaxis, xaxis, addr
Line numbers	: 6500 to 6545
Length	: 69 bytes
Zero page requirements	: 6 bytes
Registers changed	: A, X, Y

Chapter Twelve
Assembling Data and Lists

Most programs written by most advanced BASIC programmers require the manipulation of data at some stage. Everyday life revolves around manipulating data and lists correctly. A telephone directory or an address book are samples of ordered lists (though a look at my address book with its loose and sellotaped pages would make you think otherwise!) whereby each entry is in alphabetical order. Searching through the pages for a particular address or phone number is quite simple. Imagine the problems if these entries were unordered.

Performing searches, adding and deleting items from lists and sorting in machine code is not as easy as its BASIC counterparts. The procedures in this chapter cover each of these aspects and should provide you with the basis for most of the data handling you require.

The programs provided in this chapter are:

Program 12.1: Byte search.
Program 12.2: Add a byte to an ordered list.
Program 12.3: Delete a byte from an ordered list.
Program 12.4: Find minimum and maximum values in an unordered list.
Program 12.5: Delete a byte from an unordered list.
Program 12.6: Access a byte in a one-dimensional byte array.
Program 12.7: Access a byte in a two-dimensional byte array.
Program 12.8: Access a word from a one-dimensional word array.
Program 12.9: Four-byte signed integer sort.
Program 12.10: Form new list from an old list of every nth element.
Program 12.11: Perform quicksort on a four-byte integer array.

Byte search

Program 12.1 provides a single-byte binary search algorithm through

an ordered list. Just to clarify, an ordered list is a list in which its element are arranged in an ascending order. For example,

1,2,3,4,5,6...

would be an example of an ordered list, whereas

4,9,2,6,8,12,34,2,1,0...

is an example of an unordered list.

Because the list is ordered, it is not necessary for the machine code to search through the entire list. What the binary search technique does is to divide the list into half; calculate which half the search byte is in and divide this section in half again. This process continues until the search byte is located by zeroing in on it.

```
   10 REM *** SINGLE BYTE BINARY SEARCH
***
   20 PROCbin_search (&70,&71,&73,&74,&A
00)
   30 FOR loop=0 TO 150
   40 loop?&4001=loop
   50 NEXT loop
   60 ?&4000=150
   70 !&71=&4000
   80 ?&70=75
  100 CALL bin_search
  110 RESULT%=?&73
  120 IF RESULT%=0 PRINT"NOT FOUND" : EN
D
  130 PRINT"BYTE LOCATED AT +";RESULT%
  140 END
  150 :
 7000 DEF PROCbin_search (byte,list,pos,
temp,addr)
 7001 FOR PASS=0 TO 3 STEP 3
 7002 P%=addr
 7003 [
 7004           OPT PASS
 7005 .bin_search
 7006           LDY #0
 7007           LDA (list),Y
 7008           STA pos
 7009           STA temp
 7010           INY
 7011 .next_byte
 7012           LSR pos
```

Program 12.1. PROCbin_search - performs a binary search on an ordered list.

```
7013            BNE not_finished
7014            BCS over
7015            RTS
7016 .not_finished
7017            BCC over
7018            INC pos
7019 .over
7020            LDA (list),Y
7021            CMP byte
7022            BEQ byte_found
7023            BCS sub_inc
7024            TYA
7025            ADC pos
7026            CMP temp
7027            BEQ equal
7028            BCS next_byte
7029 .equal
7030            TAY
7031            JMP next_byte
7032 .sub_inc
7033            TYA
7034            SBC pos
7035            BEQ next_byte
7036            BCS set
7037            BMI next_byte
7038 .set
7039            TAY
7040            JMP next_byte
7041 .byte_found
7042            STY pos
7043            RTS
7044 ]
7045 NEXT
7046 ENDPROC
```

Program 12.1. PROCbin_search – performs a binary search on an ordered list *(cont.)*.

The program searches the list looking for the 8-bit value held in 'byte'. The list is addressed indirectly so the vector 'list' is used to hold its address, &4000 in the demo. Note that the very first byte of the list is not, in fact, an element but the length of the list itself. The list proper therefore starts at (list)+1. The variable 'pos' is used to return the position of the element in the list; if this byte contains 0 it means that the element was not found. Remember that a value of 1 would be returned if the element was the very first in the list.

The binary search begins by obtaining the length of the list from the length of list element (lines 7005 to 7009). The search proper is

then begun by executing a logical shift right on the list length byte in 'pos' (line 7012), thus dividing it by two. A result of zero indicates that the list does not contain the element being searched for and the RTS of line 7015 returns back to the calling routine leaving 'pos' holding zero. If the carry flag is set, control continues from 'over' (line 7019). The INC instruction of line 7018 is used to round any odd numbers up to an even one should the division have left an odd value in 'pos'.

The byte comparison is nothing unusual. If the byte is found, the branch to 'byte_found' is performed (line 7022) where the Y register's contents are placed in 'pos' and an RTS performed (lines 7041 to 7043). If the byte is not located then the program needs to determine which half of the section in which it is located contains the byte so that the program can halve that section. Assuming that the byte is larger than the element tested, the branch to 'sub_inc' is performed (line 7023). Here the current 'pos' is subtracted from the Y register, now transferred into the accumulator (lines 7032 to 7034) resulting in the lower portion of the list half being searched for the 'byte'. If, on the other hand, the byte is less than the element tested the branch does not take place and the 'pos' is added to the Y register so that the search continues in the upper section of the list half (lines 7024 to 7028).

The demo section of the program (lines 30 to 130) shows how the data needs to be set up before calling the subroutine. The procedural call assembles the routine at &A00 using five locations in zero page for variable storage, though only 'list' need be there. The FOR...NEXT loop then pokes an ordered list into memory from &4000 placing the number of elements in the list, 150, into the first byte (lines 30 to 60), before placing the address of the list in 'list' (line 70). The byte to be searched for - in this case 75 - is then poked into location &70 as this corresponds to 'byte'. After running the program, the result returned is

```
BYTE LOCATED AT +76
```

which is correct because 75+1=76.

An ordered addition

Figure 12.1 flowcharts very simply the steps required in adding an element to a list of ordered elements. It would be easy to look through each item in the list in turn, starting with the first element, moving onto the next and so forth until a number less than the byte and

Fig. 12.1. Flowchart for PROCordered_add.

greater than the byte to be added is found. A space can be made for the byte by moving the distal portion of the list up memory by a byte, and the byte is inserted. This is not particularly efficient especially as we now have a binary search subroutine to hand!

Program 12.2 combines Program 12.1, further illustrating the use of procedures to assemble segments of code, while the procedure PROCordered_add uses 'bin_search' as a subroutine call (line 7155) to locate the desired position of the new element to be added.

```
   10 REM *** ADDITION OF AN ELEMENT TO
***
   20 REM *** AN ORDERED LIST
***
   30 PROCbin_search (&70,&71,&73,&74,&3
000)
   40 addr=P%
   50 PROCordered_add(&70,&71,&73,&74,ad
dr)
   60 FOR loop=0 TO 254 STEP2
   70 ?(&4000+(loop/2))=loop
   80 NEXT
   90 ?&4000=127
  100 !&71=&4000
  110 ?&70=221
```

Program 12.2. PROCordered_add – adds a value to an ordered list.

```
 120 FOR N=&4000 TO (&4000+128)
 130 PRINT ~N;"  ";?N
 140 NEXT
 150 PRINT"Press a key to execute "
 160 A=GET
 170 CALL add_elememt
 180 FOR N=&4000 TO (&4000+128)
 190 PRINT ~N;"  ";?N
 200 NEXT
 210 END
 220 :
7100 DEF PROCbin_search (byte,list,pos,
temp,addr)
7101 FOR PASS=0 TO 3 STEP 3
7102 P%=addr
7103 [
7104           OPT PASS
7105 .bin_search
7106           LDY #0
7107           LDA (list),Y
7108           STA pos
7109           STA temp
7110           INY
7111 .next_byte
7112           LSR pos
7113           BNE not_finished
7114           BCS over
7115           RTS
7116 .not_finished
7117           BCC over
7118           INC pos
7119 .over
7120           LDA (list),Y
7121           CMP byte
7122           BEQ byte_found
7123           BCS sub_inc
7124           TYA
7125           ADC pos
7126           CMP temp
7127           BEQ equal
7128           BCS next_byte
7129 .equal
7130           TAY
7131           JMP next_byte
7132 .sub_inc
7133           TYA
7134           SBC pos
7135           BEQ next_byte
```

Program 12.2. PROCordered_add – adds a value to an ordered list *(cont.)*.

```
7136                BCS set
7137                BMI next_byte
7138 .set
7139                TAY
7140                JMP next_byte
7141 .byte_found
7142                STY pos
7143                RTS
7144 ]
7145 NEXT
7146 X=addr
7147 ENDPROC
7148 :
7149 DEF PROCordered_add(byte,list,pos,
temp,addr)
7150 FOR PASS=0 TO 3 STEP3
7151 P%=addr
7152 [
7153                OPT PASS
7154 .add_elememt
7155                JSR bin_search
7156                LDA pos
7157                BNE present
7158                STY pos
7159                SEC
7160                LDA temp
7161                SBC pos
7162                TAX
7163                LDA byte
7164                CMP (list),Y
7165                BCS greater
7166                INY : INX
7167                JMP get_index
7168 .greater
7169                INC pos
7170                CPX #0
7171                BEQ enter_element
7172 .get_index
7173                LDY temp
7174 .next_element
7175                LDA (list),Y
7176                INY
7177                STA (list),Y
7178                DEY
7179                DEY
7180                DEX
7181                BNE next_element
7182 .enter_element
```

Program 12.2. PROCordered_add – adds a value to an ordered list *(cont.)*.

```
7183            LDA byte
7184            LDY pos
7185            STA (list),Y
7186            INC temp
7187            LDA temp
7188            LDY #0
7189            STA (list),Y
7190 .present
7191            RTS
7192 ]
7193 NEXT
7194 ENDPROC
```

Program 12.2. PROCordered_add – adds a value to an ordered list *(cont.)*.

The PROCordered_add procedure (lines 7149 to 7194) uses the same variables/locations as the binary search procedure. Before it is called, the machine code assembled by the former expects to find the element to be added to the ordered list in 'byte', the location of the list in 'list' and the first byte of the list stating the number of elements in the list.

After the 'bin_search' subroutine call, the accumulator's contents are loaded with 'pos'. Remember, if the list did not contain the byte being searched out, this will be zero. If the byte is non-zero, the list already contains the element and need not be added – therefore the branch to 'present' (line 7157) is performed and the program completes. If the byte is zero the byte is not present, and the Y register holds the position of the last element to be examined before the search was exited. As it happens, this also corresponds to the position in the list where the binary search routine expected to find it! The Y register is therefore saved in 'pos' (line 7158) and the position where the byte to be added is to one side of this element.

Before the routine locates exactly where the byte is to be added it must first calculate how many elements must be moved up a byte to make space for the new addition. This is really quite simple as it just requires 'pos' to be subtracted from 'temp' (lines 7159 to 7161), where 'temp' is used to hold the list's length. The result is then transferred across into the X register (line 7162) to act as a loop counter when the move takes place.

Calculating the exact position of the byte in the list is facilitated with a simple comparison with the element pointed to by the Y register index (line 7164). If this sets the carry flag, the position is immediately following the element pointed to by the index register – therefore the branch to 'greater' is performed (line 7165) where 'pos' is incremented. The compare X with zero instructions (lines 7170 to

7171) test to see whether the entry position will be outside the list in which case no space needs to be made for it. If the comparison clears the carry flag then after incrementing the X register (line 7166) a jump is performed.

Moving the upper section of the list is straightforward. Starting with the highest element, each byte is read, the Y register incremented and the byte stored (lines 7172 to 7177). Subtracting two from the Y register restores the index at the next byte, while the X register acting as counter is decremented to signify one less element to move (lines 7178 to 7181). Ensuring that the move is performed in the reverse order, down memory is important so as not to overwrite other elements in the list before they are also transferred!

Finally, the 'enter_element' routine pokes the new element into its correct position and the number of elements in the list is updated by adding one to it (lines 7182 to 7189).

The BASIC demo provides details on the ordered add routine's use. The two sections of assembler are assembled (lines 30 to 50) passing the value of the program counter through 'addr' to ensure that the two subroutines occupy successive bytes in memory. The FOR...NEXT loop then pokes an ordered list into memory from &4000 which consists of only even numbers (lines 60 to 80). Lines 90 and 100 set up the number of elements in the list and the 'list' vector itself. The value to be inserted into the list, 221 – an odd number - is then poked into 'byte'.

The entire contents of the list are then printed out to ensure that only even numbers in steps of two are present (lines 120 to 160). After the 'add_element' call the list is reprinted and the new element can be seen at the top of the screen (lines 170 to 210).

An ordered delete

Deleting an element from an ordered list is performed simply by using a slightly modified Program 12.2. All that is required is first to find the position of the element in the list using the 'bin_search' routine and then move all the elements distal to the byte down memory by one, thereby overwriting the byte to be deleted. Program 12.3 lists the delete program in its entirety while the BASIC demo is similar to the one previously described.

```
   10 REM *** DELETE AN ENTRY FROM WITHI
N ***
   20 REM *** AN ORDERED LIST
  ***
   30 PROCbin_search (&70,&71,&73,&74,&3
000)
   40 addr=P%
   50 PROCordered_del(&70,&71,&73,&74,ad
dr)
   60 FOR N%=0 TO 200
   70 ?(&4001+N%)=N%
   80 NEXT
   90 ?&70=179
  100 ?&4000=200
  110 !&71=&4000
  120 CALL del_element
  130 FOR N%=0 TO 200
  140 PRINT~(N%+&4001);"  ";?(N%+&4001)
  150 NEXT
  160 END
  170 :
 7200 DEF PROCbin_search (byte,list,pos,
temp,addr)
 7201 FOR PASS=0 TO 3 STEP 3
 7202 P%=addr
 7203 [
 7204            OPT PASS
 7205 .bin_search
 7206            LDY #0
 7207            LDA (list),Y
 7208            STA pos
 7209            STA temp
 7210            INY
 7211 .next_byte
 7212            LSR pos
 7213            BNE not_finished
 7214            BCS over
 7215            RTS
 7216 .not_finished
 7217            BCC over
 7218            INC pos
 7219 .over
 7220            LDA (list),Y
 7221            CMP byte
 7222            BEQ byte_found
 7223            BCS sub_inc
 7224            TYA
 7225            ADC pos
```

Program 12.3. PROCordered_del – deletes ■ value from an ordered list.

```
7226            CMP temp
7227            BEQ equal
7228            BCS next_byte
7229 .equal
7230            TAY
7231            JMP next_byte
7232 .sub_inc
7233            TYA
7234            SBC pos
7235            BEQ next_byte
7236            BCS set
7237            BMI next_byte
7238 .set
7239            TAY
7240            JMP next_byte
7241 .byte_found
7242            STY pos
7243            RTS
7244 ]
7245 NEXT
7246 X=addr
7247 ENDPROC
7248 :
7249 DEF PROCordered_del(byte,list,pos,
temp,addr)
7250 FOR PASS=0 TO 3 STEP 3
7251 P%=addr
7252 [
7253            OPT PASS
7254 .del_element
7255            JSR bin_search
7256            LDA pos
7257            BEQ all_done
7258            INY
7259 .next_element
7260            LDA (list),Y
7261            DEY
7262            STA (list),Y
7263            INY
7264            INY
7265            CPY temp
7266            BCC next_element
7267            BEQ next_element
7268            LDA temp
7269            SBC #1
7270            LDY #0
7271            STA (list),Y
7272 .all_done
```

Program 12.3. PROCordered_del – deletes a value from an ordered list *(cont.)*.

```
7273              RTS
7274 ]
7275 NEXT
7276 ENDPROC
```

Program 12.3. PROCordered_del - deletes ■ value from an ordered list *(cont.)*.

A maximum minimum

The ability to be able to locate the maximum and minimum values in a list is important - for example, in processing data from the ADVAL channels to determine a range of results. Program 12.4 performs this task on an unordered list; in an ordered list these would be the last and first bytes respectively in the list!

```
   10 REM *** FIND MINIMUM AND MAXIMUM
 ***
   20 REM *** VALUES N AN UNORDERED LIST
 ***
   30 PROCmax_min_list(&70,&71,&72,&C00)
   40 !&72=&4000
   50 FOR loop=1 TO 100
   60 loop?&4000=RND(255)
   70 NEXT
   80 ?&4000=100
   90 CALL minmax
  100 PRINT "Mininum value was :";?&70
  110 PRINT "Maximum value was :";?&71
  120 END
  130 :
 7300 DEF PROCmax_min_list(min,max,list,
addr)
 7301 FOR PASS=0 TO 3 STEP 3
 7302 P%=addr
 7303 [          OPT PASS
 7304 .minmax
 7305              LDY #0
 7306              LDA (list),Y
 7307              TAX
 7308              INY
 7309              LDA (list),Y
 7310              STA min
 7311              STA max
 7312 .next_byte
 7313              DEX
 7314              BEQ all_done
```

Program 12.4. PROCmax_min_list – finds the maximum and minimum values in an unordered list.

```
7315             INY
7316             LDA (list),Y
7317             CMP min
7318             BCS test_max
7319             STA min
7320 .test_max
7321             CMP max
7322             BCC next_byte
7323             BEQ next_byte
7324             STA max
7325             JMP next_byte
7326 .all_done
7327             RTS
7328 ]
7329 NEXT
7330 ENDPROC
```

Program 12.4. PROCmax_min_list - finds the maximum and minimum values in an unordered list *(cont.)*.

The routine finds these values by taking the first element from the list and then using this initially as the maximum and minimum values. Then each of the remaining elements in the list are compared in turn. If an element is found to be larger than the present maximum value it becomes the new maximum value. Similarly, if an element is located that is smaller than the current minimum value it takes the current minimum value's place. When the last element in the list has been sampled, the maximum and minimum values have been located.

The 'minmax' routine performs this get and compare procedure. The address of the unordered list is held within the vector 'list' while the variables 'min' and 'max' are used as stores for the two extremes. As with the previous list operations, the first byte in the list holds its length. The subroutine begins by accessing this length byte and moving it across into the X register to act as a counter after which the first element is read and placed in the two variable stores (lines 7304 to 7311).

The main loop of the program is entered at line 7312. The X register counter is decremented, and if zero all the elements have been shifted through so the program exits (lines 7313 to 7314). The indexing register is incremented and the next element in the list sought (lines 7315 to 7316). The element in the accumulator is then tested against that in 'min'. If this clears the carry flag a smaller element is indicated so this is stored as the new minimum value. If the carry is set by the comparison a larger value than 'min' is indicated so a branch to 'test_max' is performed (lines 7318 to 7320). Here, a comparison against 'max' takes place. If the byte in the accumulator

is found to be greater, it is stored at 'max', otherwise the next element in the list is sought out (lines 7321 to 7325).

The BASIC primer pokes 100 random single-byte values into a list starting at &4000 (lines 50 to 70) and the maximum and minimum values are ascertained by the 'minmax' routine.

An un-ordered delete

Program 12.5 shows how a byte can be deleted from an unordered list. Because the list is unordered, the binary search technique employed in the ordered lists cannot be used; instead, starting at the front of the list, each byte must be compared in turn. Once the byte is located, all that is required is to move all the distal elements remaining down through memory by a single byte, thus overwriting the deleted byte.

```
   10 REM *** DELETE ITEM FROM UNORDERED
  LIST ***
   20 PROCunordered_del(&70,&71,&C00)
   30 ?&70=255
   40 !&71=&4000
   50 FOR N=1 TO 100
   60 ?(&4000+N)=N
   70 ?&4000=100
   80 NEXT
   90 ?&4050=255
  100 FOR N=&4000 TO &4064
  110 PRINT~N;"  ";?N
  120 NEXT
  130 A=GET
  140 CALL &C00
  150 FOR N=&4000 TO &4064
  160 PRINT~N;"  ";?N
  170 NEXT
  180 END
  190 :
 7400 DEF PROCunordered_del(byte,list,ad
dr)
 7401 FOR PASS=0 TO 3 STEP3
 7402 P%=addr
 7403 [          OPT PASS
 7404            LDY #0
 7405            LDA (list),Y
 7406            TAX
```

Program 12.5. PROCunordered_del – deletes a byte from an unordered list.

```
7407           LDA byte
7408 .next
7409           INY
7410           CMP (list),Y
7411           BEQ delete
7412           DEX
7413           BNE next
7414           RTS
7415 .delete
7416           DEX
7417           BEQ updat
7418           INY
7419           LDA (list),Y
7420           DEY
7421           STA (list),Y
7422           INY
7423           JMP delete
7424 .updat
7425           LDA (list,X)
7426           SBC #1
7427           STA (list,X)
7428           RTS
7429 ]
7430 NEXT
7431 ENDPROC
```

Program 12.5. PROCunordered_del - deletes a byte from an unordered list *(cont.)*.

As with the other list processing programs, the address of the list is held in the vector 'list' while the first element in the list itself is its length. The byte to be deleted is placed in 'byte' prior to the call. Note that only the first occurrence of the 'byte' is deleted, not all occurrences.

The BASIC program sets up an unordered list (well, it's actually ordered but who cares!) and then pokes the value 255 into location &4050 (now its unordered!). The list is displayed both prior to and after the machine code call to show that the element has indeed been deleted from the list (lines 30 to 170).

First bytes

In many respects, a one-dimensional byte array can be thought of simply as a list either ordered or unordered. The purpose of Program 12.6 is to calculate the absolute address of an element in the byte array by summing the array's base address and index, and then to extract that byte from the array.

```
   10 REM **GET BYTE FROM BYTE ARRAY**
   20 PROCbyte_array (&70,&71,&C00)
   30 FOR array=0 TO 255
   40 ?(array+&4000)=array
   50 NEXT
   60 !&71=&4000
   70 ?&70=100
   80 CALL byte_array
   90 PRINT"Element in array was:";?&70
  100 END
  110 :
 7500 DEF PROCbyte_array (subscript,arra
y,addr)
 7501 FOR pass=0 TO 3 STEP 3
 7502 P%=addr
 7503 [
 7504           OPT pass
 7505 .byte_array
 7506           LDA subscript
 7507           CLC
 7508           ADC array
 7509           STA array
 7510           BCC over
 7511           INC array+1
 7512 .over
 7513           LDY #0
 7514           LDA (array),Y
 7515           STA subscript
 7516           RTS
 7517 ]
 7518 NEXT
 7519 ENDPROC
```

Program 12.6. PROCbyte_array – extracts a value from a one-dimensional byte array.

The assembler requires two variables to be passed into it: 'subscript' is the index into the array while 'array' is its base address. Because 'subscript' is a single-byte value the array may only be a maximum of 256 bytes in length. The addition of 'array' and 'subscript' is performed in lines 7506 to 7511, then using indirect addressing the element is extracted and stored in 'subscript' (lines 7513 to 7515).

The BASIC tester sets up an ordered byte array at &4000 then extracts the 100th element (lines 20 to 90). Note that, unlike a list, the byte array does not need its length to be placed in the first byte of the array, which therefore starts from the address given by 'array' rather than this address plus one.

Accessing a byte from a two-dimensional byte array is a little less

straightforward as there are two subscripts to take into consideration. These two subscripts are the row length and the column length. The resultant program is listed as Program 12.7 and basically it works by multiplying the row subscript by the row size and then adding the column subscript to its result. This result is then added to the base address of the array to give an absolute address.

```
   10 REM *** ACCESSING A TWO DIMENSIONA
L ***
   20 REM *** BYTE ARRAY ANYWHERE IN RAM
  ***
   30 PROCtwodim_byte(&70,&72,&74,&76,&7
8,&3000)
   40 FOR count=1 TO 32
   50 ?(count+&4000)=count
   60 NEXT
   70 !&70=2
   80 !&72=4
   90 !&74=8
  100 !&78=&4000
  110 CALL twodimbyte
  120 @%=0
  130 PRINT'''
  140 PRINT"Address of element in array:
 &";
  150 PRINT~!&78 AND &FFFF
  160 PRINT''"Byte located here :";
  170 PRINT?&70
  180 END
  190 :
 7530 DEF PROCtwodim_byte (subscript1,su
bscript2,sub_size,temp,array,addr)
 7531 FOR PASS=0 TO 3 STEP 3
 7532 P%=addr
 7533 [
 7534           OPT PASS
 7535 .twodimbyte
 7536           LDA #0
 7537           STA temp
 7538           STA temp+1
 7539           LDX #17
 7540           CLC
 7541 .multiply
 7542           ROR temp+1
 7543           ROR temp
 7544           ROR subscript1+1
 7545           ROR subscript1
```

Program 12.7. PROCtwodim_byte – extracts a value from a two-dimensional byte array.

```
7546            BCC no_add
7547            CLC
7548            LDA sub_size
7549            ADC temp
7550            STA temp
7551            LDA sub_size+1
7552             ADC temp+1
7553            STA temp+1
7554 .no_add
7555            DEX
7556            BNE multiply
7557            LDA subscript1
7558            CLC
7559            ADC subscript2
7560            STA subscript1
7561            LDA subscript1+1
7562            ADC subscript2+1
7563            STA subscript1+1
7564            LDA array
7565            CLC
7566            ADC subscript1
7567            STA array
7568            LDA array+1
7569            ADC subscript1+1
7570            STA array+1
7571            LDY #1
7572            LDA (array),Y
7573            STA subscript1
7574            RTS
7575 ]
7576 NEXT
7577 ENDPROC
```

Program 12.7. PROCtwodim_byte – extracts a value from a two-dimensional byte array *(cont.)*.

The program commences by clearing two bytes at 'temp' which will act as a partial product during the multiplication procedure which is based on a standard shift and add type of affair. The X register is then initialised as a counter, to count out the shifts required during the multiplication (lines 7536 to 7539). The 'multiply' routine (lines 7541 to 7556) then performs the row subscript×row length multiplication. When this is completed, the second subscript, the column, is added to the product of the multiplication (lines 7558 to 7563) and then to the base address of the array itself (lines 7565 to 7570). Finally, the array element is loaded into the accumulator and placed at 'subscript1'.

The BASIC program sets up the two-dimensional byte array using concurrent numbers. Of course, the array is stored physically in

memory as a continuous list but is implemented as depicted in Figure 12.2, consisting of 4 rows of 8 columns. The position of any point in the array is given by (row,column), therefore the byte at (2,5) would be 22. The two-byte subscripts are poked into their two-byte locations at 'subscript1' and 'subscript2' (lines 70 and 80). Line 90 then places the row length into the two-byte variable 'sub_size'. After calling the machine code, the absolute address of the element is extracted from 'array' and the byte that is located there is printed (lines 110 to 170).

		COLUMN							
		0	1	2	3	4	5	6	7
ROW	0	1	2	3	4	5	6	7	8
	1	9	10	11	12	13	14	15	16
	2	17	18	19	20	21	22	23	24
	3	25	26	27	28	29	30	31	32

Fig. 12.2. Construction of a two-dimensional byte array.

Word arrays

Program 12.8 takes the one-dimensional byte array program a step further and implements the extraction of a two-byte word from a one-dimensional word array. As each word entry is two bytes long, all that the program needs to do to calculate the address of a particular element is to multiply the subscript by two and then add this to the base address of the array.

```
   10 REM *** GET WORD FROM SINGLE WORD
ARRAY ***
   20 PROCword_array (&70,&72,&C00)
   30 FOR  array=0 TO 255
   40 ?(array+&4000)=array
   50 NEXT
   60 !&70=100
   70 !&72=&4000
   80 CALL word_array
   90 PRINT"Word element is :";!&70 AND
&FFFF
  100 END
  110 :
```

Program 12.8. PROCword_array – extracts a value from a one-dimensional word array.

```
 7600 DEF PROCword_array (subscript,arra
y,addr)
 7601 FOR pass=0 TO 3 STEP 3
 7602 P%=addr
 7603 [
 7604             OPT pass
 7605 .word_array
 7606             LDA subscript
 7607             ASL A
 7608             STA subscript
 7609             LDA subscript+1
 7610             ROL A
 7611             STA subscript+1
 7612             CLC
 7613             LDA array
 7614             ADC subscript
 7615             STA array
 7616             LDA array+1
 7617             ADC subscript+1
 7618             STA array+1
 7619             LDY #0
 7620             LDA (array),Y
 7621             STA subscript
 7622             INY
 7623             LDA (array),Y
 7624             STA subscript+1
 7625             RTS
 7626 ]
 7627 NEXT
 7628 ENDPROC
```

Program 12.8. PROCword_array - extracts a value from a one-dimensional word array *(cont.)*

To perform the multiplication on the two-byte subscript, a two-byte shift left is performed using the ASL ROL combination (lines 7606 to 7611). The double subscript is then added to 'array' (lines 7612 to 7618) and the two-byte word extracted and placed in 'subscript' (lines 7619 to 7624).

Integer sort

Handling single-byte sorts is relatively easy but arrays of multi-byte numbers are more complex to handle. Program 12.9 provides an algorithm to sort a set of four-byte integer numbers stored consecutively in memory. Note that it assumes signed values.

```
   10 REM *** 4 BYTE SIGNED INTERGER SOR
T ***
   20 PROCsort32 (&70,&72,&74,&76,&C00)
   30 INPUT"How many numbers to sort ?"c
ount
   40 ?&76=count-1
   50 buffer=&4000
   60 ?&74=0:?&75=&40
   70 FOR random=0 TO  count-1
   80 !(buffer+4*random)=RND
   90 NEXT random
  100 CALL &C00
  110 FOR look=0 TO count-1
  120 PRINT !(buffer+4*look)
  130 NEXT
  140 END
  150 :
 7700 DEF PROCsort32 (one,two,vector,cou
nt,addr )
 7701 FOR pass=0 TO 3 STEP3
 7702 P%=addr
 7703 [
 7704             OPT pass
 7705 .entry
 7706             LDA vector
 7707             STA two
 7708             LDA vector+1
 7709             STA two+1
 7710             LDA #0
 7711             STA loop
 7712 .once_more
 7713             LDY #0
 7714             LDA two+1
 7715             STA one+1
 7716             LDA two
 7717             STA one
 7718             CLC
 7719             ADC #4
 7720             STA two
 7721             BCC no_inc
 7722             INC two+1
 7723 .no_inc
 7724             LDX #4
 7725             SEC
 7726 .subtract
 7727             LDA (two),Y
 7728             SBC (one),Y
 7729             INY
```

Program 12.9. PROCsort32 - sorts a list of four-byte values.

```
7730            DEX
7731            BNE subtract
7732            BVC vclear
7733            EOR #&80
7734 .vclear
7735            EOR #0
7736            BPL no_swap
7737            DEY
7738 .swap
7739            LDA (one),Y
7740            STA store
7741            LDA (two),Y
7742            STA (one),Y
7743            LDA store
7744            STA (two),Y
7745            DEY
7746            BPL swap
7747 .no_swap
7748            INC loop
7749            LDA loop
7750            CMP count
7751            BNE once_more
7752            DEC count
7753            BNE entry
7754            RTS
7755 .loop
7756            EQUS" "
7757 .store
7758            EQUS" "
7759 ]
7760 NEXT
7761 ENDPROC
```

Program 12.9. PROCsort32 – sorts a list of four-byte values *(cont.)*

The procedure passes four variables used by the assembler. The variable 'vector' is, as its name implies, a zero page vector that the machine code expects to contain the start address of the array. On entry to the code at 'entry' this address is passed into the two working vectors 'one' and 'two' (how's that for originality!), lines 7705 to 7711. The sort routine is, in fact, a 'bubble sort' procedure. This works by working through the numbers in the array and comparing sets of two contiguous numbers. If the lower number is greater than the second number then they are swapped over. This process continues through all the numbers in the array until there are none left. The net effect is that numbers seem to bubble up through the array, thus the terminology. The disadvantage of a bubble sort is that it is very slow.

although this is not so noticeable in machine code. However, it is not nearly as fast as the quicksort described later.

Let's get back to the program description. After seeding both vectors, the address in 'two', which points to the second of the two integers, is placed in 'one' (lines 7713 to 7717) and the vector 'two' is incremented by 4 to give it the address of the next vector in the array (lines 7718 to 7722). The X register is used as a byte counter so is initialised to 4 (line 7724) whereupon the integer at 'one' is subtracted from the integer at 'two'. If on completion of the subtraction the overflow flag is set, it is necessary to reverse the sign of the most significant bit of the result now in the accumulator. This is performed in line 7733, and the EOR of line 735 will set the negative flag to the value of the most significant bit of the accumulator. This process is particularly important as the negative flag is used to determine whether a swap is needed or not. If the flag is clear, no swap is indicated and a branch to 'no_swap' performed. The swap takes place, therefore, if the negative flag is set and is carried out by lines 7738 to 7746.

The final bytes of code (lines 7747 to 7753) test to see if the bubble sort has been completed, i.e. when a pass through it results in no swaps being performed after which control is passed back to BASIC.

The BASIC demo routine at the start of the program pokes a random array of four-byte integers into a 'buffer' from &4000. After the sorting routine has been completed the array is displayed to show each four-byte integer in ascending order.

New lists for old

Program 12.10 uses an assembler routine to form a new list from an old one. What actually happens is that it extracts every nth item and places this in a list buffer elsewhere to form the list. This has many applications. For example, a list of four-byte integer numbers could be sorted into sub-lists of correspondingly significant bytes grouping all the most significant bytes together and so forth, which is useful if look-up tables are being used by another section of the program.

The program is straightforward and the assembler expects three variables. The first 'source' is the address of the main list, while 'new' is the address of the new list. Note that these are not implemented as vectored addresses but this could be used if desired. Finally, 'step' is the increment size determining the elements to be extracted.

After initialising the index registers, the main program loop is

```
  10 REM *** FORM NEW LIST FROM OLD ***
  20 PROCnew_list (&4000,&4200,5,&C00)
  30 FOR N=0 TO 100
  40 ?(&4001+N)=N
  50 NEXT
  60 ?&4000=100
  70 CALL &C00
  80 C=?&4200
  90 FOR N=0 TO C-1
 100 PRINT?(&4201+N)
 110 NEXT
 120 END
 130 :
7770 DEF PROCnew_list (source,new,step,
addr)
7771 FOR pass=0 TO 3 STEP 3
7772 P%=addr
7773 [          OPT pass
7774           LDY #0
7775           LDX #0
7776 .next_byte
7777           LDA source+1,Y
7778           STA new+1,X
7779           INX
7780           TYA
7781           CLC
7782           ADC #step
7783           TAY
7784           CMP source
7785           BCC next_byte
7786           STX new
7787           RTS
7788 ]
7789 NEXT
7790 ENDPROC
```

Program 12.10. PROCnew_list - creates a sublist from a main list.

entered at 'next_byte'. The first byte of the source list is accessed and saved in the new list (lines 7777 to 7778). The 'new' list indexing register is then incremented and the 'source' list indexing register incremented by the value of 'step'. As the first byte of the source list holds its length, this byte is compared to the new index value to see if the end of the list has been passed. If not, the loop branches to repeat again, otherwise the contents of X are saved at 'new' to provide its length details.

A fast quicksort!

The final program in this chapter, Program 12.11, provides a very fast four-byte integer sorting routine based on the 'quicksort' algorithm, also known in some areas of Highbury as a fastsort!

The quicksort procedure is less well known than the more illustrious bubble sort so a brief description of its working is probably useful. Consider the set of ten simple integers shown arranged randomly in Figure 12.3(a). One of these numbers is selected and is called the key. In the figure, the key is 46 and is shaded to make its position clear. Working from right to left, the key is in turn compared with each byte until a smaller byte is encountered. First time through, the first smaller value encountered is the third one in, 24. The key then swaps positions with this byte as shown in Figure 12.3(b). Next, the search process is repeated but this time, working from left to right, the first byte encountered that is larger than the key is swapped with the key – 70 in this instance (Figure 12.3(c)). The process repeats again until no more swaps are possible, as Figure 12.3(d) shows.

(a)	46	35	30	70	39	75	48	24	63	50
(b)	24	35	30	70	39	75	48	46	63	50
(c)	24	35	30	46	39	75	48	70	63	50
(d)	24	35	30	39	46	75	48	70	63	50

Fig. 12.3. (a) Assigning the key in a quicksort. (b) The array after the first quicksort pass. (c) The array after the second quicksort pass. (d) The array after the third quicksort pass.

Looking at Figure 12.3(d) carefully shows that it is divided into two halves. All the numbers on the left of the key are smaller than the key itself while those on the right are larger. In other words, the key has now found its final position in the list. The two sections of the list can now be sorted independently using new keys, and then the sections these provide and so on until the quicksort is completed.

Because the number of elements to be sorted reduces each time through the quicksort the time taken for it to complete its task is substantially quicker than the bubble sort method described earlier which processes the whole array each time through. In fact, to sort

1000 four-byte integers using the bubble sort would take around 50 seconds, compared with under two seconds for the quicksort. A BASIC version of the quicksort is only slightly slower than the assembler bubble sort!

```
   10 REM *** FOUR BYTE INTEGER FASTSORT
 ***
   20 PROCquick(&3900,&70,&72,&74,&76,&7
8,&7A,&80)
   30 !&80=&5000:!(&80+2)=20
   40 FOR N=0 TO 20 STEP4
   50 !(&5000+N)=RND:NEXT
   60 CALL fastsort
   70 FOR N=0TO 20 STEP4
   80 PRINT!(&5000+N):NEXT
   90 END
  100 :
 7800 DEF PROCquick(softstk,left,right,c
urrent_left,current_right,stack,middle,d
ata)
 7801 FOR pass=0 TO 3 STEP 3
 7802 P%=&4000
 7803 [           OPT pass
 7804 .fastsort
 7805           LDA #softstk MOD 256
 7806           STA stack
 7807           LDA #softstk DIV 256
 7808           STA stack+1
 7809           LDA data+2
 7810           STA left
 7811           LDA data+3
 7812           STA left+1
 7813           LDY #1
 7814 .setup
 7815           LDA (left),Y
 7816           STA current_left,Y
 7817           DEY
 7818           BPL setup
 7819           LDY #2
 7820 .shift_two
 7821           ASL current_left
 7822           ROL current_left+1
 7823           DEY
 7824           BNE shift_two
 7825           LDA data
 7826           CLC
 7827           ADC current_left
 7828           STA right
```

Program 12.11. PROCquick - implements a four-byte quicksort routine.

```
7829             LDA data+1
7830             ADC current_left+1
7831             STA right+1
7832             LDA data
7833             SEC
7834             SBC #4
7835             STA left
7836             LDA data+1
7837             SBC #0
7838             STA left+1
7839 .save_value
7840             LDA left
7841             CLC
7842             ADC #4
7843             STA current_left
7844             LDA left+1
7845             ADC #0
7846             STA current_left+1
7847             LDA right
7848             STA current_right
7849             SEC
7850             SBC current_left
7851             BNE over
7852             LDA right+1
7853             SBC current_left+1
7854             BNE over
7855             JMP pull
7856 .over
7857             LDA right+1
7858             STA current_right+1
7859             JSR swap
7860             LDY #3
7861 .back
7862             LDA (current_left),Y
7863             STA key,Y
7864             DEY
7865             BPL back
7866 .adjust_right
7867             LDA current_right
7868             SEC
7869             SBC #4
7870             STA current_right
7871             BCS compare_hiright
7872             DEC current_right+1
7873 .compare_hiright
7874             LDA current_left+1
7875             CMP current_right+1
7876             BCC not_right
```

Program 12.11. PROCquick – implements a four-byte quicksort routine *(cont.).*

```
7877          LDA current_left
7878          CMP current_right
7879          BEQ equal
7880 .not_right
7881          LDX #4
7882          LDY #0
7883          SEC
7884 .compare_keyright
7885          LDA (current_right),Y
7886          SBC key,Y
7887          INY
7888          DEX
7889          BNE compare_keyright
7890          BVC no_mask
7891          EOR #&80
7892 .no_mask
7893          AND #&FF
7894          BPL adjust_right
7895          DEY
7896 .exchange
7897          LDA (current_right),Y
7898          STA (current_left),Y
7899          DEY
7900          BPL exchange
7901 .adjust_left
7902          LDA current_left
7903          CLC
7904          ADC #4
7905          STA current_left
7906          BCC compare_lefthigh
7907          INC current_left+1
7908 .compare_lefthigh
7909          LDA current_left+1
7910          CMP current_right+1
7911          BCC not_left
7912          LDA current_left
7913          CMP current_right
7914          BEQ equal
7915 .not_left
7916          LDX #4
7917          LDY #0
7918          SEC
7919 .compare_keyleft
7920          LDA key,Y
7921          SBC (current_left),Y
7922          INY
7923          DEX
7924          BNE compare_keyleft
```

Program 12.11. PROCquick – implements a four-byte quicksort routine *(cont.).*

```
7925            BVC no_mask_again
7926            EOR #&80
7927 .no_mask_again
7928            AND #&FF
7929            BPL adjust_left
7930            DEY
7931 .exchange_over
7932            LDA (current_left),Y
7933            STA (current_right),Y
7934            DEY
7935            BPL exchange_over
7936            BMI adjust_right
7937 .equal
7938            LDY #3
7939 .exc_loop
7940            LDA key,Y
7941            STA (current_left),Y
7942            DEY
7943            BPL exc_loop
7944            LDA current_left
7945            SEC
7946            SBC left
7947            STA word
7948            LDA current_left+1
7949            SBC left+1
7950            STA word+1
7951            LDA right
7952            SEC
7953            SBC current_left
7954            STA temp
7955            LDA right+1
7956            SBC current_left+1
7957            STA temp+1
7958            LDA word
7959            SEC
7960            SBC temp
7961            LDA word+1
7962            SBC temp+1
7963            BCC save_hi
7964 .save_lo
7965            LDY #0
7966            LDA left
7967            STA (stack),Y
7968            INY
7969            LDA left+1
7970            STA (stack),Y
7971            INY
7972            LDA current_left
```

Program 12.11. PROCquick – implements a four-byte quicksort routine *(cont.)*.

```
7973              STA (stack),Y
7974              STA left
7975              INY
7976              LDA current_left+1
7977              STA (stack),Y
7978              STA left+1
7979              JMP update
7980 .save_hi
7981              LDY #2
7982              LDA right
7983              STA (stack),Y
7984              INY
7985              LDA right+1
7986              STA (stack),Y
7987              LDY #0
7988              LDA current_left
7989              STA (stack),Y
7990              STA right
7991              INY
7992              LDA current_left+1
7993              STA (stack),Y
7994              STA right+1
7995 .update
7996              CLC
7997              LDA stack
7998              ADC #4
7999              STA stack
8000              BCC update1
8001              INC stack+1
8002 .update1
8003              JMP save_value
8004 .pull
8005              LDA stack
8006              SEC
8007              SBC #softstk MOD 256
8008              BNE pull1
8009              LDA stack+1
8010              SBC #softstk DIV 256
8011              BNE pull1
8012              RTS
8013 .pull1
8014              LDA stack
8015              SEC
8016              SBC #4
8017              STA stack
8018              BCS pull2
8019              DEC stack+1
8020 .pull2
```

Program 12.11. PROCquick implements a four-byte quicksort routine *(cont.)*.

```
8021            LDY #3
8022 .pull3
8023            LDA (stack),Y
8024            STA left,Y
8025            DEY
8026            BPL pull3
8027            JMP save_value
8028 .swap
8029            LDA current_right
8030            SEC
8031            SBC current_left
8032            AND #&F8
8033            STA middle
8034            LDA current_right+1
8035            SBC current_left+1
8036            STA middle+1
8037            LSR middle+1
8038            ROR middle
8039            LDA current_left
8040            CLC
8041            ADC middle
8042            STA middle
8043            LDA current_left+1
8044            ADC middle+1
8045            STA middle+1
8046            LDY #3
8047 .swap_loop
8048            LDA (current_left),Y
8049            STA word
8050            LDA (middle),Y
8051            STA (current_left),Y
8052            LDA word
8053            STA (middle),Y
8054            DEY
8055            BPL swap_loop
8056            RTS
8057 .key  EQUD 0
8058 .word EQUW 0
8059 .temp EQUW 0
8060 ] NEXT
8061 ENDPROC
```

Program 12.11 PROCquick - implements a four-byte quicksort routine *(cont.)*.

The main areas of operation of Program 12.11 are as follows:

Lines 7805 to 7808: Set up vector for software stack which will be used to hold pointers and data for future reference by the routine.
Lines 7809 to 7813: Save base address of the integer array in 'left'.

Lines 7814 to 7818: Seed integer into the 'current_left' position.
Lines 7819 to 7855: Seed next integer into 'current_right' position and test to see if they are equal. If both are equal, then pull pointers and data from stack and move onto next subsection.
Lines 7856 to 7860: If items are not equal perform the swap.
Lines 7861 to 7865: Then save key for future reference.
Lines 7866 to 7900: Compare key with integers to the right of it and perform swap if greater.
Lines 7901 to 7936: Compare key with integers to the left of it and perform swap if less than.
Lines 7937 to 8043: Place key back in 'current_left'.
Lines 7944 to 7963: Now save pointers of unsorted sections of integer array on software stack. Concentrate on smallest section first.
Lines 7964 to 8003: Routine to push pointers and data items onto software stack.
Lines 8004 to 8027: Routine to pull all pointers and data items off software stack.
Lines 8028 to 8055: Subroutine to perform the key integer swap.

Two sets of two variables are used by the assembler routine. The boundaries of the current section half being sorted are held in 'left' and 'right'. The current left- and right-hand numbers being tested with the key are held in 'current_left' and 'current_right' respectively.

The BASIC primer sets up an array of random integer values at &5000. After calling the quicksort, the sorted array is displayed (lines 20 to 90).

Program fact sheets

Program 12.1

Procedure title	: PROCbin_search
Variables required	: byte, list, pos, temp, addr
Line numbers	: 7000 to 7046
Length	: 57 bytes
Zero page requirements	: 5 bytes
Registers changed	: A, X, Y

Program 12.2

Procedure title	: PROCordered_add (also requires PROCbin_search

Variables required	: byte, list, pos, temp, addr
Line numbers	: 7100 to 7194
Length	: 115 bytes
Zero page requirements	: 5 bytes
Registers changed	: A, X, Y

Program 12.3

Procedure title	: PROCordered_del (also requires PROCbin_search)
Variables required	: byte, list, pos, temp, addr
Line numbers	: 7200 to 7276
Length	: 87 bytes
Zero page requirements	: 5 bytes
Registers changed	: A, X, Y

Program 12.4

Procedure title	: PROCmax_min_list
Variables required	: min, max, list, addr
Line numbers	: 7300 to 7330
Length	: 36 bytes
Zero page requirements	: 4 bytes
Registers changed	: A, X, Y

Program 12.5

Procedure title	: PROCunordered_del
Variables required	: byte, list, addr
Line numbers	: 7400 to 7431
Length	: 36 bytes
Zero page requirements	: 3 bytes
Registers changed	: A, X, Y

Program 12.6

Procedure title	: PROCbyte_array
Variables required	: subscript, array, addr
Line numbers	: 7500 to 7519
Length	: 18 bytes
Zero page requirements	: 3 bytes
Registers changed	: A, Y

Program 12.7

Procedure title	: PROCtwodim_byte

Variables required	:	subscript1, subscript2, sub_size, temp, array, addr
Line numbers	:	7530 to 7577
Length	:	68 bytes
Zero page requirements	:	10 bytes
Registers changed	:	A, X, Y

Program 12.8

Procedure title	:	PROCword_array
Variables required	:	subscript, array, addr
Line numbers	:	7600 to 7628
Length	:	34 bytes
Zero page requirements	:	3 bytes
Registers changed	:	A, X, Y

Program 12.9

Procedure title	:	PROCsort32
Variables required	:	one, two, vector, count, addr
Line numbers	:	7700 to 7761
Length	:	86 bytes
Zero page requirements	:	8 bytes
Registers changed	:	A, X, Y

Program 12.10

Procedure title	:	PROCnew_list
Variables required	:	source, new, step, addr
Line numbers	:	7770 to 7790
Length	:	25 bytes
Zero page requirements	:	1 byte
Registers changed	:	A, X, Y

Program 12.11

Procedure title	:	PROCquick
Variables required	:	softstk, left, right, current_left, current_right, stack, middle, data
Line numbers	:	7800 to 8061
Length	:	437 bytes
Zero page requirements	:	14 bytes
Registers changed	:	A, X, Y

Chapter Thirteen
Communication

An important part of good software is good communication between the program and the user. Excellent software is very often degraded because the writer has not made any attempt to make the program user-friendly by presenting instructions neatly onto the screen and using sensible keys for inputting information. This chapter provides some short but important procedures that will enable the programmer both to neaten up screen presentation and have the program input data with minimal fuss. Most programs are based around the excellent set of operating system commands, thus reducing the amount of coding. The routines included are:

Program 13.1 : Perform a CLS
Program 13.2 : Perform VPOS and POS.
Program 13.3 : Perform SPC.
Program 13.4 : Perform STRING$.
Program 13.5 : Perform TAB (X).
Program 13.6 : Perform TAB (X,Y).
Program 13.7: Perform GET.
Program 13.8: Perform INKEY.
Program 13.9 : Super quick key test.
Program 13.10: Read line.
Program 13.11: Read a VDU definition.
Program 13.12: Hexadecimal to ASCII.
Program 13.13: Packed BCD to ASCII.
Program 13.14: ASCII to packed BCD.

Onto the screen

The first six programs presented here deal with formatting text on the screen. Program 13.1 performs a simple CLS to clear the screen, by printing a control code 12 through OSWRCH.

Knowing where the cursor is at a particular time is another useful function to perform. In BASIC, the POS and VPOS functions return

```
  10 REM*** CLEAR SCREEN -CLS ***
  20 PROCcls (&C00)
  30 PRINT"PRESS ■ KEY TO CLEAR SCREEN"
  40 A=GET
  50 CALL &C00
  60 END
  70 :
8000 DEF PROCcls (addr)
8001 P%=addr
8002 [
8003 .clear_screen
8004                LDA #12
8005                JSR &FFEE
8006                RTS
8007 ]
8008 ENDPROC
```

Program 13.1. PROCcls – performs CLS.

the horizontal (X axis) and vertical (Y axis) components of the cursor. These two functions have a direct equivalent within the MOS, an OSBYTE &86 call. Program 13.2 shows that the X and Y coordinates of the cursor are returned in the respective index registers which can be saved for evaluation.

```
  10 REM *** DO POS & VPOS ***
  20 PROCcursor (&70,&71,&C00)
  30 CLS
  40 PRINTTAB(10,10);
  50 CALLcursor
  60 PRINT'"Cursor positions were :"
  70 PRINT"POS = ";?&70
  80 PRINT"VPOS= ";?&71
  90 END
 100 :
8010 DEF PROCcursor (pos,vpos,addr)
8011 P%=&C00
8012 [OPT 2
8013 .cursor
8014             LDA #&86
8015             JSR &FFF4
8016             STX pos
8017             STY vpos
8018             RTS
8019 ]
8020 ENDPROC
```

Program 13.2. PROCcursor – returns the X,Y coordinates of the text cursor.

Program 13.3 imitates the BASIC command SPC, to print a specified number of spaces from the current cursor position. The number of spaces to be printed should be passed into the procedure via the variable 'spc'. At assembly time. this variable is treated as an immediate value being loaded directly into the X register to act as a simple loop control. Prior to entering 'loop', the accumulator is loaded with 32, the ASCII code of a space, and the required number is printed.

```
  10  REM *** DO MACHINE CODE SPC ***
  20 CLS
  30 INPUT"How many spaces ?"spc
  40 PROCspace (spc,&C00)
  50 CALL space
  60 END
  70 :
8030 DEF PROCspace (spc,addr)
8031 P%=addr
8032 [OPT 2
8033 .space
8034             LDX  #spc
8035             LDA  #32
8036 .loop
8037             JSR &FFEE
8038             DEX
8039             BNE loop
8040             RTS
8041 ]
8042 ENDPROC
```

Program 13.3. PROCspace - performs SPC.

STRINGS is a BASIC command that allows a specified number of the same string to be printed. This can result in a great saving of memory space. For example, it is much neater to print 40 asterisks using

PRINT STRINGS (40, "*")

rather than enclosing 40 asterisks inside quotes or from a machine code point of view in an ASCII data table. Program 13.4 emulates this command by printing a string located at 'buffer', 'num' number of times.

The program commences by loading the Y register with the 'num' count (line 8055) and then setting the X register to zero (line 8057), which is to be used as an absolute index into 'buffer'. The get and display loop is embodied in lines 8058 to 8063. Each character is

```
  10 REM *** DO STRING$ ***
  20 CLS
  30 INPUT"Enter your string :"$&C50
  40 INPUT"How many times    :"num
  50 PROCstring (&C50,num,&C00)
  60 CALL string
  70 END
  80 :
8050 DEF PROCstring (buffer,num,addr)
8051 FOR pass=0 TO 2 STEP 2
8052 P%=addr
8053 [OPT pass
8054 .string
8055            LDY #num
8056 .count
8057            LDX #0
8058 .next_chr
8059            LDA buffer,X
8060            JSR &FFE3
8061            INX
8062            CMP #13
8063            BNE next_chr
8064            DEY
8065            BNE count
8066            RTS
8067 ]
8068 NEXT
8069 ENDPROC
```

Program 13.4 PROCstring - performs STRING$

extracted from 'buffer' and printed in turn until a carriage return has been printed. The Y register is decremented and the 'count' loop repeated until it reaches zero. Note that in the code the carriage return at the end of the string (put there by BASIC's INPUT statement – line 30) is printed, so that each string occupies a new line rather than being printed continuously across the screen. The CMP #13 test could be performed earlier so that the program exists before issuing a return if so required.

Positioning text on the screen is performed using the TAB function. There are two bytes of TAB, namely TAB(X) and TAB(X,Y). The simplest way to perform a TAB(X) is to print the move cursor right code, ASCII 9, the required number of times. Program 13.5 details the assembler, the required value of X passing into the procedure through 'xpos'. Once again, a simple loop is used printing the code 9 through OSWRCH until the X register has been decremented to zero. It is worth bearing in mind that this routine is in

```
  10 REM *** DO TAB(X)***
  20 CLS
  30 INPUT"Number of tabs :"xpos
  40 PROCtabx(xpos,&C00)
  50 CLS
  60 CALL tabx
  70 PRINT"*"'
  80 PRINT"* marks the TAB position"
  90 END
 100 :
8080 DEF PROCtabx (xpos,addr)
8081 P%=addr
8082 [OPT 2
8083 .tabx
8084           LDA #9
8085           LDX #xpos
8086 .xtab
8087           JSR &FFEE
8088           DEX
8089           BNE xtab
8090           RTS
8091 ]
8092 ENDPROC
```

Program 13.5. PROCtabx - performs TAB(X).

fact different from the one given in Program 13.3 as it has no effect on any text the cursor passes over. Only the cursor is moved and no spaces are output as in the former program.

TAB(X,Y) is performed through OSWRCH using the driver code 31 followed by first the X and then the Y coordinate to tab to. Program 13.6 uses immediate addressing to pass the two TAB parameters into the assembler via 'xpos' and 'ypos'.

```
  10 REM *** DO TAB(X,Y) ***
  20 CLS
  30 INPUT"Tab X position :"xpos
  40 INPUT"Tab Y position :"ypos
  50 PROCtabxy (xpos,ypos,&C00)
  60 CLS
  70 CALL tabxy
  80 PRINT"*"'
  90 PRINT"* marks the TAB position"
 100 END
 110 :
8100  DEF PROCtabxy (xpos,ypos,addr)
8101 P%=addr
8102 [OPT 2
```

Program 13.6. PROCtabxy – performs TAB(X,Y).

```
8103 .tabxy
8104            LDA #31
8105            JSR &FFEE
8106            LDA #xpos
8107            JSR &FFEE
8108            LDA #ypos
8109            JSR &FFEE
8110            RTS
8111 ]
8112 ENDPROC
```

Program 13.6. PROCtabxy – performs TAB(X,Y) *(cont.)*.

The key to detection

I doubt if there are many programs that do not require some sort of interaction from the user at the keyboard, whether it be a simple 'press key to continue' affair or more complex data input. Whatever it is, the need to perform the task efficiently and correctly is important.

A simple GET type keyboard read can be performed by calling OSRDCH at &FFE0 directly (see Program 13.7). This call waits for a key to be pressed and returns with its ASCII value in the accumulator. However, when using this call it is important to test to see if the ESCAPE key was the key pressed. This can be performed simply by comparing the accumulator contents with &1B (line 8126). If the key was pressed then it *must* be acknowledged with an OSBYTE &7E call (lines 8128 to 8129) otherwise the MOS will hang up or do crazy things!

```
  10  REM ** TEST FOR KEY **
  20  CLS
  30  PRINT"Press key to test for";
  40  chr$=GET$
  50  chr=ASC(chr$)
  60  PROCgetkey(chr,&C00)
  70  PRINT''"Press ";chr$;" to end";
  80  CALL getstring
  90  PRINT'''"Finished!"
 100  END
 110 :
8120  DEF PROCgetkey (chr,addr)
8121  FOR pass=0 TO 2 STEP 2
8122  P%=addr
8123  [OPT pass
8124  .getstring
```

Program 13.7. PROCgetkey – performs GET.

```
8125                    JSR &FFE0
8126                    CMP #&1B
8127                    BNE no_escape
8128                    LDA #&7E
8129                    JSR &FFF4
8130  .no_escape
8131                    CMP #chr
8132                    BNE getstring
8133                    RTS
8134 ]
8135  NEXT
8136  ENDPROC
```

Program 13.7. PROCgetkey – performs GET *(cont.)*

Using OSBYTE &81, an INKEY timed input can be performed. The index registers are used to hold the wait period which is specified in centiseconds. Program 13.8 shows how it is set up in the procedure PROCinkey. Prior to the actual OSBYTE call an *FX15,1 is

```
  10  REM *** DO MACHINE CODE INKEY ***

  20 PROCinkey (1000,&70,&C00)
  30 CLS
  40 PRINT"Press  key within time limit
"
  50 CALL inkey
  60 PRINT"Key pressed was :";CHR$(?&70
)
  70 END
  80 :
8140 DEF PROCinkey (wait,result,addr)
8141 FOR pass=0 TO 2 STEP 2
8142 P%=addr
8143 [OPT pass
8144 .inkey
8145                LDA #15
8146                LDX #1
8147                LDY #0
8148                JSR &FFF4
8149                LDA #&81
8150                LDX #wait MOD 256
8151                LDY #wait DIV 256
8152                JSR &FFF4
8153                CPY #&1B
8154                BNE no_escape
8155                LDA #&7E
8156                JSR &FFF4
```

Program 13.8. PROCinkey – performs INKEY.

```
8157 .no_escape
8158            STX result
8159            RTS
8160 ]
8161 NEXT
8162 ENDPROC
```

Program 13.8. PROCinkey – performs INKEY *(cont.)*.

performed to flush all input buffers (lines 8145 to 8148). The wait period is passed into the assembler via the variable 'wait', the high and low bytes are loaded into the respective registers using the MOD and DIV operators (lines 8149 to 8152). As with the previous procedure, the ESCAPE key should be tested for and acknowledged with the appropriate call if need be (lines 8153 to 8156). Note that in this instance the escape code is returned in the Y register. If a key is detected in the allotted time period it is returned from OSBYTE in the X register and both the Y register and carry flag are clear. If no character is detected within the time period, Y returns containing &FF and the carry is set.

OSBYTE &81 can also be used to perform a single keyboard scan if it is called with the Y register holding &FF and the X register the negative INKEY value.

The demonstration program performs an INKEY (1000) equivalent, which basically causes the MOS to look at the keyboard for 10 seconds or until a key is pressed.

Both of the above two routines suffer from one drawback. They are slow! Well, in machine code terms they are. Consider that the fastest MOS-based routine, using OSBYTE &81 with X holding the negative inkey value will take at least 300 cycles and anything up to 1200 cycles. Program 13.9 does the whole scan in a mere 12 cycles and what's more it can test for two keys being pressed at once!

The code assembled by PROCkeytest looks at locations &EC and &ED. If a key is pressed at any time then the MOS places zero into &ED and &EC contains the key's number. The actual numbers stored by the MOS are internal key numbers +128. For almost all purposes the internal key numbers are the negative INKEY numbers made positive and then decremented by one. For example, C is equal to INKEY(−83) so its internal number is calculated as ABS(−83)−1 or 83−1=82. Testing for C using 'keytest' therefore requires a test for 82+128=210.

If two keys are pressed almost simultaneously then &ED contains the number of the first key pressed and &EC the second key. If no keys are detected then both these bytes are zero.

```
  10 REM *** QUICK TEST FOR KEY ***
  20 PROCkeytest (&900)
  30 VDU15
  40 CALL start
  50 END
  60 :
8300 DEFPROCkeytest (addr)
8301 FOR pass=0 TO 2 STEP 2
8302 P%=addr
8303 [
8304              OPT pass
8305 .start
8306              LDA&ED
8307              BEQ check_EC
8308              JSR valid_key
8309              BEQ check_EC
8310              JSR&FFEE
8311 .check_EC
8312              LDA&EC
8313              BEQ start
8314              JSR valid_key
8315              BEQ start
8316              JSR&FFEE
8317              JMP start
8318 .valid_key
8319              CMP#&F0
8320              BNE next1
8321              PLA
8322              PLA
8323              LDA#15
8324              JSR&FFF4
8325              RTS
8326 .next1
8327              CMP#&E1
8328              BNE next2
8329              LDA#&5A
8330              RTS
8331 .next2
8332              CMP#&C2
8333              BNE next3
8334              LDA#&58
8335              RTS
8336 .next3
8337              CMP#&D2
8338              BNE next4
8339              LDA#&43
8340              RTS
8341 .next4
```

Program 13.9. PROCkeytest - a 12-cycle key test.

```
8342            CMP#&E3
8343            BNE next5
8344            LDA#&56
8345            RTS
8346 .next5
8347            LDA#0
8348            RTS
8349 ]
8350 NEXT
8351 ENDPROC
```

Program 13.9 PROCkeytest – a 12-cycle key test *(cont.)*.

As it stands, the routine has been set up to look for Z, X, C, V and ESCAPE. The hex begins by peeking &ED. If this is zero then &EC can be tested straightaway so the branch to 'check_EC' is performed (lines 8306 to 8307). The subroutine 'valid_key' tests for each of the above keys. The first tested is ESCAPE, code &F0 (line 8319). If it is detected then the RTS address is pulled from the stack and the MOS entered with 15 in the accumulator to handle the ESCAPE. The following bytes then look for each key in turn. The codes for each are:

&E1 = Z
&C2 = X
&D2 = C
&E3 = V

If any of these compare, the letter is printed out. The 'check_EC' routine works exactly the same.

If you run the program and then press either the Z, X, C, or V keys then you'll see just how fast this key test routine is. The screen half fills with letters before you can lift your finger off the key! Finally, I should point out that this method is not condoned by Acorn as it is MOS-dependent. It will work on OS 1.0 and OS 1.2 but I haven't tried it on OS 0.1 so it may not work if you are using this version of MOS.

The GET single key type routines could be employed to read in a string of characters, placing each one into a defined buffer until a set number of characters is reached or a return character detected. This does involve some extra coding, though, as a loop and buffer would need to be implemented. A neater way is to use the MOS line input routine OSWORD &00. This is a very useful call as it allows a number of parameters to be specified regarding the characters being input. Figure 13.1 details the parameter block. The first two bytes contain the address of the input buffer, the second byte the maximum

XY+0	:	LSB of input buffer address
XY+1	:	MSB of input buffer address
XY+2	:	Maximum number of characters
XY+3	:	Minimum ASCII value of character acceptable
XY+4	:	Maximum ASCII value of character acceptable

Fig. 13.1. OSWORD &00 parameter block.

number of characters to be placed in the buffer, while the last two bytes determine the maximum and minimum acceptable ASCII characters that will be accepted and placed in the buffer!

This OSWORD call does have one major disadvantage, though. Although only characters in the specified ASCII range will be placed into the buffer, any other characters presses will be echoed to the screen even though they are not deposited in the buffer.

Program 13.10 provides a suitable procedure. The parameter

```
   10  REM ** READ LINE FROM INPUT **
   20  PROCinputline(&70,&C00,10,ASC"A",
 ASC"Z",&4000)
   30  CALL &4000
   40  PRINT$&C00
   50  END
 8170  DEF PROCinputline(block,B%,L%,max
,min,addr)
 8171  FOR pass=0 TO 3 STEP3
 8172  P%=addr
 8173  [OPT pass
 8174             LDA #B% MOD 256
 8175             STA block
 8176             LDA #B% DIV 256
 8177             STA block+1
 8178             LDA #L%
 8179             STA block+2
 8180             LDA #max
 8181             STA block+3
 8182             LDA #min
 8183             STA block+4
 8184             LDA #0
 8185             LDX #block MOD 256
 8186             LDY #block DIV 256
 8187             JSR &FFF1
 8188             RTS
 8189  ]
 8190  NEXT
 8191  ENDPROC
```

Program 13.10. PROCinputline – input a line of text.

block address for the call is defined in 'block' while B% determines the input line buffer location; L% the number of characters acceptable, i.e. the buffer's maximum length; and 'max', 'min' the acceptable character range.

Program 13.11 will read the bit map definition of any ASCII or defined VDU character. OSWORD &0A performs the task and all that is required prior to the read is to define a nine-byte parameter block, 'block' in the program. The ASCII code of the character to be read should be located in the first byte of the parameter block and on return the following eight bytes contain the character's definition starting with the top row of the character.

```
   10 REM **READ VDU CHR DEFINITION**
   20 CLS
   30 PRINT"PRESS A KEY TO DISLAY ITS DE
FINITION";
   40 chr$=GET$
   50 chr=ASC(chr$)
   60 PROCread_chr(&70,chr,&4000)
   70 CALL &4000
   80 CLS
   90 PRINT"THE DEFINITION OF ";chr$;" I
S :"
  100 FOR N=&71 TO &78:PRINT?N:NEXT
  110 END
 8200 DEF PROCread_chr(block,chr,addr%)
 8201 FOR pass=0 TO 3 STEP 3
 8202 P%=addr%
 8203 [OPT pass
 8204             LDA #chr
 8205             STA block
 8206             LDA #10
 8207             LDX #block MOD 256
 8208             LDY #block DIV 256
 8209             JSR &FFF1
 8210             RTS
 8211 ]
 8212 NEXT
 8213 ENDPROC
```

Program 13.11. PROCread_chr – reads the eight-byte definition of any character.

A simple change

The final three programs provide some simple conversion routines.

Program 13.12 will convert the hexadecimal value at 'byte' and print it to the screen as two ASCII hex bytes. Thus if 'byte' held &FF then the letters F and F will be printed. The program works as follows. After loading the byte for conversion into the accumulator, the logical AND ensures that only the lowest four bits are set (lines 8233 to 8234). After setting the decimal flag, the addition of &90 to binary values 0 to 9 will result in a value of &90 to &99 with the carry flag clear. A further addition of &40 will convert these characters to values in the range &30 to &39 with the carry set. Remember that decimal addition is in operation so that adding 1 to &99 will give a result of &00 rather than &9A.

```
   10 REM *** SIMPLE HEX TO ASCII ***
   20 PROChex_asc(&70,&71,&72,&C00)
   30 ?&70=255
   40 CALL &C00
   50 PRINT'''
   60 PRINTCHR$(?&71);CHR$(?&72)
   70 END
   80 :
 8230 DEF PROChex_asc(byte,high,low,addr
)
 8231 P%=addr
 8232 [
 8233             LDA byte
 8234             AND #15
 8235             SED
 8236             CLC
 8237             ADC #&90
 8238             ADC #&40
 8239             CLD
 8240             STA low
 8241             LDA byte
 8242             LSR A
 8243             LSR A
 8244             LSR A
 8245             LSR A
 8246             SED
 8247             CLC
 8248             ADC #&90
 8249             ADC #&40
 8250             CLD
 8251             STA high
 8252             RTS
 8253 ]
 8254 ENDPROC
```

Program 13.12. PROChex_asc – convert a hexadecimal number into two ASCII values.

Adding &90 to the binary values &A to &F results in a byte in the range &00 to &05 with the carry set. A further addition of &40 (plus the set carry) converts this to values &41 to &46, the ASCII codes for the letters A to F.

The byte is then saved and the next four bits treated likewise after shifting them into the lower nibble position with four logical shifts. Both ASCII codes are stored at 'high' and 'low' for future reference. If you wish not to save the two results but to print them directly then remember that the high nibble must be treated first and then the low nibble as the digits are printed, most significant first, on the screen.

Program 13.13 converts a packed BCD digit into its component ASCII codes. To perform the conversion the byte must first be transformed into its two component nibbles, which should be placed in the low nibble position before having bit 5 forced to 1 using ORA #&30. The high nibble is treated first. After loading the packed byte from 'bcd' it is pushed onto the hardware stack for future reference. The high nibble is then shifted into the low nibble position (lines 8263

```
   10 REM *** PACKED BCD TO ASCII ***
   20 PROCbcd_ascii(&70,&71,&72,&C00)
   30 ?&70=&12
   40 CALL &C00
   45 PRINT''
   50 PRINT CHR$(?&72); CHR$(?&71)
   60 END
   70 :
 8260 DEF PROCbcd_ascii(bcd,low,high,add
r)
 8261 P%=addr
 8262 [
 8263           LDA bcd
 8264           PHA
 8265           LSR A
 8266           LSR A
 8267           LSR A
 8268           LSR A
 8269           ORA #&30
 8270           STA high
 8271           PLA
 8272           AND #15
 8273           ORA #&30
 8274           STA low
 8275           RTS
 8276 ]
 8277 ENDPROC
```

Program 13.13. PROCbcd_ascii – converts a packed BCD byte into two ASCII values.

to 8268). Bit 5 is then forced and the ASCII character code placed in 'high' – it could at this point be printed using JSR &FFEE instead. The stack is pulled and the high nibble masked out with an AND (lines 8271 to 8272). Bit 5 is forced and the result placed in 'low' (lines 8273 to 8274).

Performing the reverse conversion, two ASCII digits to packed BCD, involves reversing the procedure as depicted in Program 13.14. The high digit is extracted from 'high' shifted right so that bit 5 is lost and only the binary bits remain. This byte is pushed onto the hardware stack. The 'low' digit is loaded into the accumulator, the low nibble preserved, and the stack pointer copied into the X register (lines 8289 to 8291). The two digits have now been stripped of bit 5, and all that is now required is to merge them together. This is done by logically ORing the two together (lines 8292). The X register is incremented and copied back into the stack pointer thus 'popping' the byte from the stack. Finally the result is placed at 'bcd'.

```
   10 REM *** ASCII TO PACKED BCD ***
   20 PROCasc_bcd(&70,&71,&72,&C00)
   30 ?&70=ASC("6")
   40 ?&71=ASC("9")
   50 CALL &C00
   60 PRINT~?&72
   70 END
   80 :
 8280 DEF PROCasc_bcd(high,low,bcd,addr)
 8281 P%=addr
 8282 [
 8283             LDA high
 8284             ASL A
 8285             ASL A
 8286             ASL A
 8287             ASL A
 8288             PHA
 8289             LDA low
 8290             AND #15
 8291             TSX
 8292             ORA &101,X
 8293             INX
 8294             TXS
 8295             STA bcd
 8296             RTS
 8297 ]
 8298 ENDPROC
```

Program 13.14. PROCasc_bcd – converts two ASCII values into a packed BCD byte.

Program fact sheets

Program 13.1

Procedure title	: PROCcls
Variables required	: addr
Line numbers	: 8000 to 8008
Length	: 6 bytes
Zero page requirements	: none
Registers changed	: A

Program 13.2

Procedure title	: PROCcursor
Variables required	: pos, vpos, addr
Line numbers	: 8010 to 8020
Length	: 10 bytes
Zero page requirements	: 2 bytes
Registers changed	: A, X, Y

Program 13.3

Procedure title	: PROCspace
Variables required	: spc, addr
Line numbers	: 8030 to 8042
Length	: 11 bytes
Zero page requirements	: none
Registers changed	: A, X

Program 13.4

Procedure title	: PROCstring
Variables required	: buffer, num, addr
Line numbers	: 8050 to 8069
Length	: 19 bytes
Zero page requirements	: none
Registers changed	: A, X, Y

Program 13.5

Procedure title	: PROCtabx
Variables required	: xpos, addr
Line numbers	: 8080 to 8092
Length	: 17 bytes
Zero page requirements	: none
Registers changed	: A, X

Program 13.6

Procedure title	: PROCtabxy
Variables required	: xpos, ypos, addr
Line numbers	: 8100 to 8112
Length	: 16 bytes
Zero page requirements	: none
Registers changed	: A

Program 13.7

Procedure title	: PROCgetkey
Variables required	: chr, addr
Line numbers	: 8120 to 8136
Length	: 17 bytes
Zero page requirements	: none
Registers changed	: A

Program 13.8

Procedure title	: PROCinkey
Variables required	: wait, result, addr
Line numbers	: 8150 to 8162
Length	: 31 bytes
Zero page requirements	: 1 byte
Registers changed	: A, X, Y

Program 13.9

Procedure title	: PROCkeytest
Variables required	: addr
Line numbers	: 8300 to 8351
Length	: 69 bytes
Zero page requirements	: none
Registers changed	: A

Program 13.10

Procedure title	: PROCinputline
Variables required	: block, B%, L%, max, min, addr
Line numbers	: 8170 to 8191
Length	: 26 bytes
Zero page requirements	: 5 bytes
Registers changed	: A, X, Y

Program 13.11

Procedure title	: PROCread_chr
Variables required	: block, chr, addr
Line numbers	: 8200 to 8213
Length	: 14 bytes
Zero page requirements	: 9 bytes
Registers changed	: A, X, Y

Program 13.12

Procedure title	: PROChex_asc
Variables required	: byte, high, low, addr
Line numbers	: 8230 to 8254
Length	: 29 bytes
Zero page requirements	: 3 bytes
Registers changed	: A

Program 13.13

Procedure title	: PROCbcd_ascii
Variables required	: bcd, low, high, addr
Line numbers	: 8260 to 8277
Length	: 19 bytes
Zero page requirements	: 3 bytes
Registers changed	: A

Program 13.14

Procedure title	: PROCasc_bcd
Variables required	: high, low, bcd, addr
Line numbers	: 8280 to 8289
Length	: 20 bytes
Zero page requirements	: 3 bytes
Registers changed	: A, X

Chapter Fourteen
Odd One Out

This final chapter in the Portfolio draws together eight programs that offer ■ variety of functions. The programs are:

Program 14.1: Find highest IRQ.
Program 14.2: Timer 1 delay.
Program 14.3: Timer 2 delay.
Program 14.4: One second delay.
Program 14.5: Save all processor registers.
Program 14.6: Restore all processor registers.
Program 14.7: Two-byte incrementing counter.
Program 14.8: Two-byte decrementing counter.

Interrupt polling

Program 14.1 is not a complete routine as it stands as it expects extra code, written by the user, to be tagged onto it. Basically it is an interrupt polling sequence for the User VIA, capable of identifying the highest priority interrupt request on any one of the seven lines capable of having an IRQ.

In order to know which interrupt servicing routine to call, the source of the IRQ must be determined. To find this out, bit 7 of the Interrupt Flag Register (IFR7) must be tested. If this bit is set then an IRQ has been issued. The IFR is read using an OSBYTE &96 call to read Sheila. As the IFR occupies location &6D in Sheila this value is placed in the X register. After the call, the Y register contains the byte just read, which is transferred into the accumulator. If bit 7 is clear the branch to 'next_device' will be executed (lines 9006 to 9010).

What is required now is to read the Interrupt Enable Register (IER) at Sheila &6E, as a set bit in this register will give the identity of the IRQ. This is performed by lines 9012 to 9015. For an interrupt to

```
  10 REM ***   FIND HIGHEST IRQ  ***
  20 REM ***needs extra user coding***
  30 REM **to run sequence correctly**
  40 :
9000 DEF PROChighestIRQ (temp,addr)
9001 FOR pass=0 TO 3 STEP 3
9002 P%=addr
9003 [
9004           OPT pass
9005 .find IRQ
9006           LDA #&96
9007           LDX #&6D
9008           JSR &FFF4
9009           TYA
9010           BPL next_device
9011           PHA
9012           LDA #&96
9013           LDX #&6E
9014           JSR &FFF4
9015           STY temp
9016           PLA
9017           AND temp
9018           ASL A
9019           BMI timer1
9020           ASL A
9021           BMI timer2
9022           ASL A
9023           BMI cb1
9024           ASL A
9025           BMI cb2
9026           ASL A
9027           BMI shift_reg
9028           ASL A
9029           BMI ca1
9030           ASL A
9031           BMI ca2
9032           JMP error
9033 .timer 1
9034           JMP T1service
9035 .timer2
9036           JMP T2service
9037 .cb1
9038           JMP cb1service
9039 .cb2
9040           JMP cb2service
9041 .shift_reg
9042           JMP srservice
9043 .ca1
```

Program 14.1. PROChighestIRQ – locates the highest priority interrupt.

```
9044              JMP ca1service
9045 .ca2
9046              JMP ca2service
9047 .error
9048              \ error service routine here
9049 .next_device
9050              \ more polling here
9051 ]
9052 NEXT
9053 ENDPROC
```

Program 14.1. PROChighestIRQ – locates the highest priority interrupt *(cont.)*.

have occurred, the corresponding bits in the IFR and IER must have been set; to determine the actual bit these two bytes are logically ANDed together to preserve the set bit (line 9015 to 9016). Now all that is required is to shift the byte to condition the negative flag. Setting the negative flag will determine that the bit just shifted was the line-associated bit that caused the IRQ and thus the BMI for that test will proceed.

In Program 14.1 I have used a left to right priority system, so that bit 6 has a greater priority than bit 5. Therefore an interrupt on T1 interrupt enable has a greater priority than an interrupt on T2 and so forth. You can arrange your own priorities to suit, though the test procedure might not be a simple shift and branch sequence, and more complex coding might be required.

A timed delay

Both the timers in the User VIA can be used to produce delays. Program 14.2 uses Timer 1 to provide one 1-millisecond delay using it

```
  10 REM *** MILLISECOND DELAY USING T1
***
  20 PROCtimerone_delay (&C00)
  30 CALL millisec1
  40 END
  50 :
9060 DEF PROCtimerone_delay (addr)
9061 FOR pass=0 TO 3 STEP 3
9062 P%=addr
9063 [
9064              OPT pass
9065 .millisec1
```

Program 14.2. PROCtimerone_delay – a one millisecond delay using Timer 1.

```
9066             LDA #&97
9067             LDX #&6B
9068             LDY #0
9069             JSR &FFF4
9070             LDX #&64
9071             LDY #&E8
9072             JSR &FFF4
9073             LDX #&65
9074             LDY #3
9075             JSR &FFF4
9076             LDA #&40
9077 .loop
9078             BIT &FE6D
9079             BEQ loop
9080             LDA &FE64
9081             RTS
9082 ]
9083 NEXT
9084 ENDPROC
```

Program 14.2. PROCtimerone_delay - a one millisecond delay using Timer 1 *(cont.)*.

in its one-shot mode of operation. To place T1 into this mode, zero must be written to the Auxillary Control Register at Sheila &6B. Next the delay must be loaded into the latches. One millisecond corresponds to 1000 cycles, however, and it should be remembered that T1 has an operating overhead of 1.5 cycles, so the actual value loaded into the latches must be the actual value minus 2. Thus, 998 is to be deposited into the T1 latches. Lines 9070 to 9075 perform this using the hex equivalent &3E8; writing to the msb latch starts the timer running.

On timing out, the T1 bit in the IFR will be set. To test for this, &40, is loaded into the accumulator and the IFR tested using the BIT operation. This small loop (lines 9077 to 9079) continues until the BEQ fails, denoting time out. The T1 flag is then cleared by reading the latch (line 9080).

Program 14.3 performs a similar delay using Timer 2. Only the addresses in the program and the bit mask change.

```
  10 REM *** MILLISECOND DELAY USING T2
***
  20 PROCtimertwo_delay (&C00)
  30 CALL millisec
  40 END
  50 :
9100 DEF PROCtimertwo_delay (addr)
9101 FOR pass=0 TO 3 STEP 3
```

Program 14.3. PROCtimertwo_delay - a one millisecond delay using Timer 2.

```
9102 P%=addr
9103 [
9104            OPT pass
9105 .millisec
9106            LDA #&97
9107            LDX #&6B
9108            LDY #0
9109            JSR &FFF4
9110            LDX #&68
9111            LDY #&E8
9112            JSR &FFF4
9113            LDX #&69
9114            LDY #3
9115            JSR &FFF4
9116            LDA #&20
9117 .loop
9118            BIT &FE6D
9119            BEQ loop
9120            LDA &FE68
9121            RTS
9122 ]
9123 NEXT
9124 ENDPROC
```

Program 14.3. PROCtimertwo_delay – a one millisecond delay using Timer 2 *(cont.)*.

The timers are fine for providing very short delay loops but for substantial delays they are not really suitable. Program 14.4 will provide a 1-second delay. It does this by just executing a series of timed loops. As the clock on the Beeb operates at 2MHz, the delay loop need only count out 2000000 cycles to create the delay.

```
  10 REM *** 1.0 SECOND DELAY ***
  20 PROCdelay (&C00)
  30 INPUT"How many seconds delay ?: "w
ait
  40 TIME=0
  50 FOR loop=1 TO wait
  60 CALL &C00
  70 NEXT
  80 time%=TIME
  90 time%=(time%/100)
 100 PRINT"Time taken was :";time%;
 110 PRINT" second(s)"
 120 END
 130 :
9130 DEF PROCdelay (addr)
9131 FOR PASS=0 TO 3 STEP 3
```

Program 14.4. PROCdelay – a one second delay loop.

```
9132 P%=addr
9133 [            OPT PASS
9134              PHP
9135              PHA
9136              TXA
9137              PHA
9138              TYA
9139              PHA
9140              LDY outer
9141 .loop1
9142              TYA
9143              PHA
9144              LDX inner
9145 .loop2
9146              LDY #5
9147 .loop3
9148              DEY
9149              BNE loop3
9150              DEX
9151              BNE loop2
9152              LDY #2
9153 .loop4
9154              DEY
9155              BNE loop4
9156              PLA
9157              TAY
9158              DEY
9159              BNE loop1
9160              LDY fine
9161 .loop5
9162              DEY
9163              BNE loop5
9164              PLA
9165              TAY
9166              PLA
9167              TAX
9168              PLA
9169              PLP
9170              RTS
9171 .outer
9172              EQUB 251
9173 .inner
9174              EQUB 0
9175 .fine
9176              EQUB 197
9177 ]
9178 NEXT
9179 ENDPROC
```

Program 14.4. PROCdelay – a one second delay loop *(cont.)*.

The main loop counter is provided by 'outer' while the finer inner loop counter is 'inner'. The program commences by pushing all processor registers onto the stack thus preserving their status on return. This process takes 16 cycles (lines 9134 to 9139). The Y register is then loaded with 'outer' (4 cycles line 9140) and 'loop1' entered. This major outer loop has a smaller loop within it between lines 9145 and 9151 which takes a total of 256*31−1 cycles or 7935 cycles to execute. As the outer 'loop1' is controlled by the contents of the Y register, 251, the main loop between lines 9141 and 9159 takes 251*7964−1 or 1998963 cycles to run. In both cases, the −1 is needed because the final branch does not take place and therefore only uses 2 cycles and not the 3 allowed in the calculation.

The final 'fine' loop plus restoring the registers add a further 30+984 (the loop in lines 9162 to 9163) cycles to the overall delay. The total delay provided by the loop is therefore calculated as 1998963 + 16 + 4 + 30 + 984 = 1999997 cycles. This is obviously three cycles short of the desired delay, which doesn't really bear thinking about!

The BASIC demo asks how long a delay you would like. Because there is an overhead in the BASIC operations, don't be too surprised if you enter 20 in response to the prompt and get an answer of 23 seconds back. The extra three seconds were created by the BASIC interpreter working through the program!

Now a question. Add the following line to the program

```
25 CLS
```

and run it. Why does it seem to work twice as quick? Don't expect the answer: I'm still trying to fathom it out for myself!

```
  10 REM*SAVE ALL PROCESSOR REGISTERS*
  20 REM*DOES NOT HAVE RTS MUST BE   *
  30 REM*USED DIRECTLY IN CODE.      *
  40 :
9200 DEF PROCpush_all(addr)
9201 P%=addr
9202 [ OPT 2
9203 .pushall
9204           PHP
9205           PHA
9206           TXA
9207           PHA
9208           TYA
9209           PHA
9210 ]
9211 ENDPROC
```

Program 14.5. PROCpush_all – save all processor registers on hardware stack.

A push me pull you

The last program showed that a subroutine call need not destroy the contents of the processor registers if their contents are important. With the exception of two programs in this book all the assembler procedures alter the contents of at least the accumulator and many of the index registers as well. Programs 14.5 and 14.6 provide suitable procedures to save and then restore all processor registers. The main point to note here is that the assembler is not implemented as a subroutine; in other words it does not end with an RTS. This means that the code must be placed at the point it is needed, with the register changing hex following straight after. It would be possible to implement it as a subroutine if required though I would not recommend it as it would need some jiggery pokery with the stack to put the RTS address after the pushed register values.

```
   10 REM*RESTORE ALL PROCESSOR REGISTER
S*
   20 REM*DOES NOT HAVE RTS MUST BE *
   30 REM*USED DIRECTLY IN CODE. *
   40 :
 9220 DEF PROCpull_all(addr)
 9221 P%=addr
 9222 [ OPT 2
 9223 .pullall
 9224            PLA
 9225            TAY
 9226            PLA
 9227            TAX
 9228            PLA
 9229            PLP
 9230 ]
 9231 ENDPROC
```

Program 14.6. PROCpull_all - restore all processor registers off of the hardware stack.

Count on it

And so to the last two of the 75 programs in this book, which I do hope you have found informative and useful. The two programs implement double-byte counters, useful for loop control with a count greater than 255 or for updating ■ two-byte memory address.

Program 14.7 is an incrementing counter. The procedure first loads the start value of the counter, 'num' into the two bytes from

```
  10 REM *** TWO BYTE COUNTER ***
  20 PROCinc_count (5000,&70,&C00)
  25 CALL seed_value
  30 REPEAT
  40 PRINT?&71*256+?&70
  50 CALL plus_one
  60 UNTIL ?&71=0
  70 END
  80 :
9240 DEF PROCinc_count (num,block,addr)
9241 FOR pass=0 TO 3 STEP 3
9242 P%=addr
9243 [OPT pass
9244 .seed_value
9245                LDA #num MOD 256
9246                STA block
9247                LDA #num DIV 256
9248                STA block+1
9249 .plus_one
9250                INC block
9251                BNE no_inc
9252                INC block+1
9253 .no_inc
9254                RTS
9255 ]
9256 NEXT
9257 ENDPROC
```

Program 14.7. PROCinc_count - performs a double-byte increment

'block' (lines 9244 to 9248). The incrementing starts at 'plus_one' (line 9249) where 'block' has one added to it (line 9250). Any carry is detected by the zero flag and if set, one is added to 'block+1' else a return via 'no_inc' is performed.

```
  10 REM *** DOUBLE BYTE DECREMENT ***
  20 PROCdec_count (5000,&70,&C00)
  25 CALL seed_value
  30 REPEAT
  40 PRINT?&71*256+?&70
  50 CALL minus_one
  60 UNTIL ?&71=0
  70 END
  80 :
9260 DEF PROCdec_count (num,block,addr)
9261 FOR pass=0 TO 3 STEP 3
9262 P%=addr
9263 [OPT pass
9264 .seed_value
```

Program 14.8. PROCdec_count - performs a double-byte decrement.

```
9265                LDA #num MOD 256
9266                STA block
9267                LDA #num DIV 256
9268                STA block+1
9269 .minus_one
9270                LDA block
9271                BNE no_dec
9272                DEC block+1
9273 .no_dec
9274                DEC block
9275                RTS
9276 ]
9277 NEXT
9278 ENDPROC
```

Program 14.8 PROCdec_count - performs a double-byte decrement *(cont.)*

The application program in lines 20 to 60 shows that once a count value has been seeded only 'plus_one' should be called to increment the block.

Decrementing a two-byte counter is a little less straightforward (Program 14.8). As before, the count start value is first seeded through 'num' (lines 9264 to 9268). The decrement process begins at 'minus_one' by first loading the low byte of the count at 'block' into the accumulator (line 9270). If this byte should be zero then the decrement must take the high page byte into consideration and decrement this (line 9272). Finally, the low byte is decremented (line 9274).

As with the previous program, after the initial set up it is 'no_dec' that must be called to perform the decrement as the BASIC demo illustrates.

Program fact sheets

Program 14.1

Procedure title	: PROChighestIRQ
Variables required	: temp, addr
Line numbers	: 9000 to >9050
Length	: variable
Zero page requirements	: none
Registers changed	: A, X, Y

Program 14.2

Procedure title	:	PROCtimerone_delay
Variables required	:	addr
Line numbers	:	9060 to 9084
Length	:	34 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 14.3

Procedure title	:	PROCtimertwo_delay
Variables required	:	addr
Line numbers	:	9100 to 9124
Length	:	34 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 14.4

Procedure title	:	PROCdelay
Variables required	:	addr
Line numbers	:	9130 to 9179
Length	:	48 bytes
Zero page requirements	:	none
Registers changed	:	none

Program 14.5

Procedure title	:	PROCpush_all
Variables required	:	addr
Line numbers	:	9200 to 9211
Length	:	6 bytes
Zero page requirements	:	none
Registers changed	:	none

Program 14.6

Procedure title	:	PROCpull_all
Variables required	:	addr
Line numbers	:	9220 to 9231
Length	:	6 bytes
Zero page requirements	:	none
Registers changed	:	A, X, Y

Program 14.7

Procedure title	: PROCinc_count
Variables required	: num, block, addr
Line numbers	: 9240 to 9257
Length	: 15 bytes
Zero page requirements	: 2 bytes
Registers changed	: A

Program 14.8

Procedure title	: PROCdec_count
Variables required	: num, block, addr
Line numbers	: 9260 to 9278
Length	: 17 bytes
Zero page requirements	: 2 bytes
Registers changed	: A

Appendix

Some Portfolio Programs in Bar Code Form

The next few pages contain several of the programs in the Portfolio in bar code form. Owners of the MEP bar code reader will be able to read these directly into the Beeb following the instructions in the Bar Code Reader Handbook.

Full details of the MEP bar code reader can be obtained from:

Micro Electronics Educational Program
Cheviot House
Coach Lane Campus
Newcastle-upon-Tyne NE7 7XA

Because of space requirements, and to make the programs easier to read in, each of the programs have been extensively compacted by using shorter variable names and multistatement lines. To allow programs to be listed in a more readable form the first of the programs presented is BASFORM.

The programs presented are:

(a) BASFORM (Program 4.1)
(b) ASSFORM (Program 4.2)
(c) PACK (Program 9.2)
(d) KEYS2 (Program 2.2)
(e) ERROR (Program 9.1)
(f) VARS (Program 3.1)

BASFORM (Program 4.1)

START

END

ASSFORM (Program 4.2)

START

END

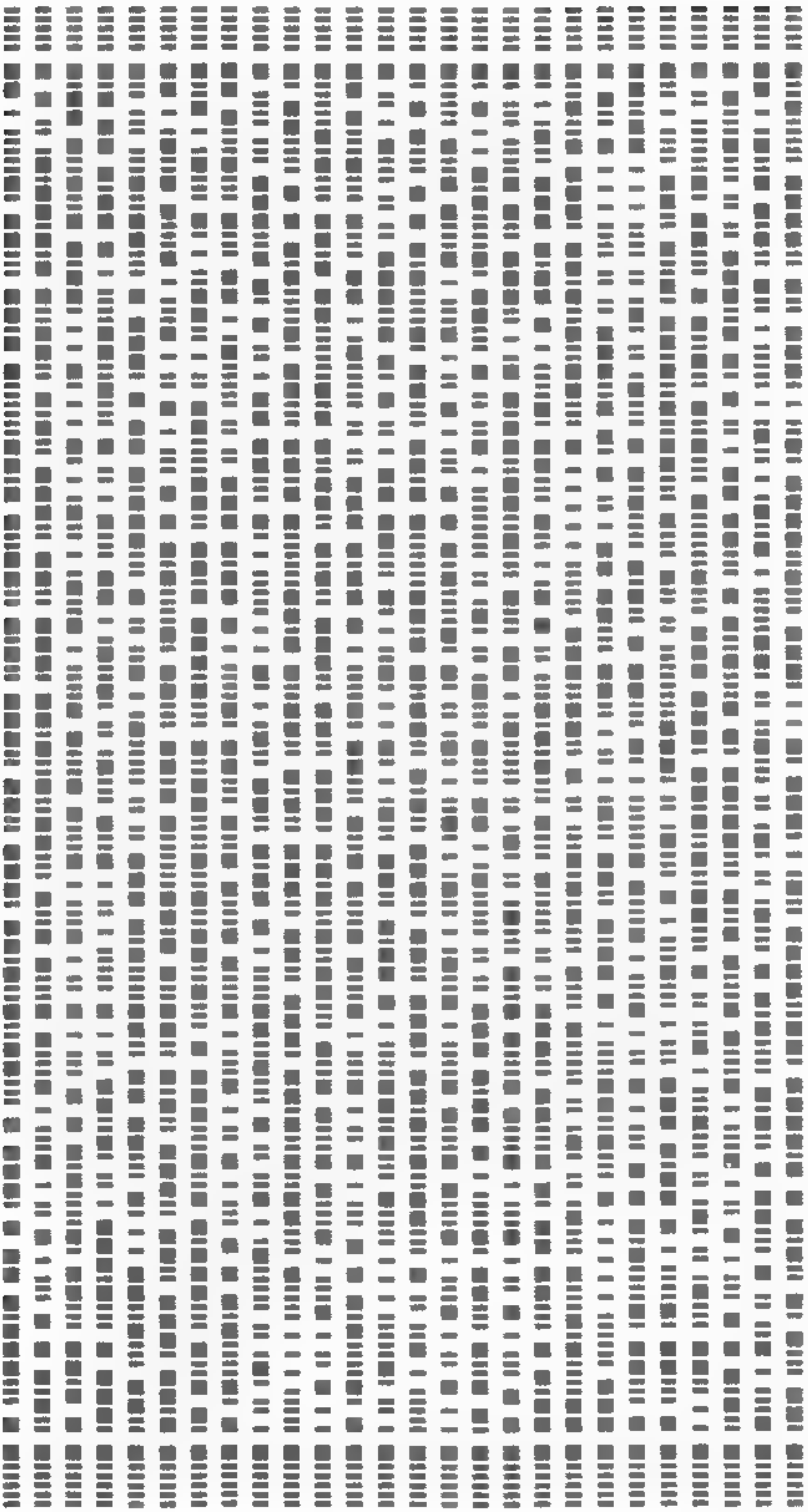
PACK (Program 9.2)

START

END

KEYS2 (Program 2.2)

START



ERROR (Program 9.1)

START

END

VARS (Program 3.1)

START

END

Index

OVER 5.5K OF MACHINE CODE FACILITIES!

This outstanding collection of machine code routines and utilities sets out – ready to use – what every user needs to get the best from the BBC Micro.

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The Author

Bruce Smith is Technical Editor of *Acorn User*. His interest in computers was born four years ago when he purchased an Acorn Atom. Since then he has written numerous books, many on the subject of machine code programming. He is a regular contributor to many magazines including *Acorn User, A & B Computing* and *Digital and Micro Electronics.*

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